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DEPARTMENT OF CONSERVATION
AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY OF THE YORKTOWN, POQUOSON WEST, AND POQUOSON EAST QUADRANGLES, VIRGINIA

GERALD H. JOHNSON

REPORT OF INVESTIGATIONS 30

VIRGINIA DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

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GEOLOGY OF THE YORKTOWN, POQUOSON WEST, AND POQUOSON EAST QUADRANGLES, VIRGINIA

by

GERALD H. JOHNSON [1]

ABSTRACT

The Yorktown, Poquoson West, and Poquoson East quadrangles are areas in the lower York-James Peninsula portion of the Atlantic Coastal Plain. Their morphology is dominated by a series of plains and scarps that range in elevation from about 90 feet north of Grove to sea level along Chesapeake Bay and along the York and James rivers. The plains and scarps are complex depositional-erosional features, which were formed during the Pleistocene. Dissection of the plains is most advanced on the higher plains and less extensively on the lower plains.

The sediments in this area dip seaward at 2 to 7 feet per mile, except in the Yorktown area where a reversal of the regional dip occurs. The Yorktown Formation of late Miocene, and possibly early Pliocene age, is subdivided into six lithofacies. An offshore submarine bar complex, consisting of cross-bedded biofragmental sand (cross-bedded coquina facies), developed in the Yorktown-Chuckatuck area, forming a lagoon to the west in which the sandy-silt facies accumulated and to the east of which the shelly-sand and silty-sand facies were deposited in marine waters 50 to 125 feet deep. After the barrier had been breached or drowned, the coquina and *Chama* facies were deposited in warm, shallow seas that covered most of the area mapped.

Alternating periods of erosion and aggradation took place in the Pleistocene. Following an extended period of emergence and erosion, sea level rose to 100 feet elevation in the middle Pleistocene and the Windsor Formation was deposited in a lagoonal-tidal flat-barrier bar environment. Later sea level fell in stages to below present sea level and another episode of erosion ensued. During the Sangamon (?) interglacial age, sea level rose to 45 to 50 feet elevation and the Norfolk Formation accumulated in fluvial-estuarine (clayey-sand and marsh facies), and nearshore

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marine (sand, sandy-clay, and silty-sand facies) environments. During late Norfolk time sea level fell to 20 feet elevation and earlier Norfolk deposits were extensively eroded. Entrenchment of major streams occurred during the Wisconsin glacial age. With the establishment of present sea level in the late Holocene, beaches, marshes and streams assumed their present state.

The Yorktown Formation in the Yorktown and Grafton areas contains marl and sand which are utilized in the construction of highways. Economically extractable deposits of sand and gravel occur in Norfolk Formation in the Grafton and Denbigh areas.

INTRODUCTION

The Yorktown, Poquoson West, and Poquoson East quadrangles are areas in the coastal plain of southeastern Virginia (Figure 1). The quadrangles are bounded by parallels 37° 07′ 30″ and 37° 15′ north and meridians 76° 15′ and 76° 37′ 30″ west and comprise a land area of approximately 100 square miles; the remainder is covered by water (Figure 2). The quadrangles include portions of York, James City, and Gloucester counties and a portion of the City of Newport News. Most of the area is covered by mixed deciduous and conifer forests; extensive salt marshes are found along Chesapeake Bay. Little agricultural activity is being conducted in this area in the wake of urbaniza-

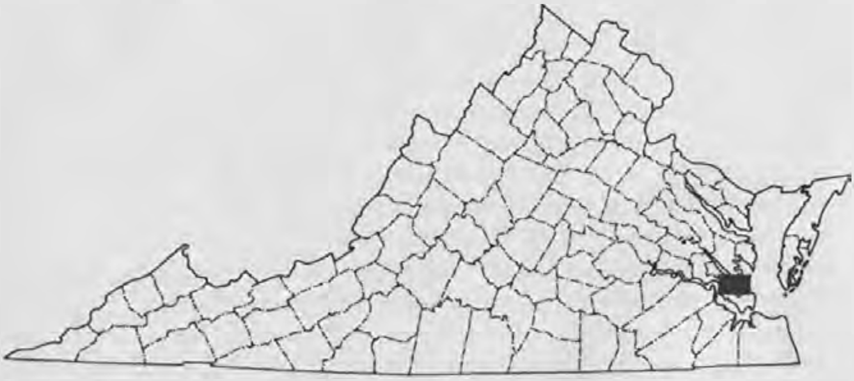

Figure 1. Index map showing location of area studied.

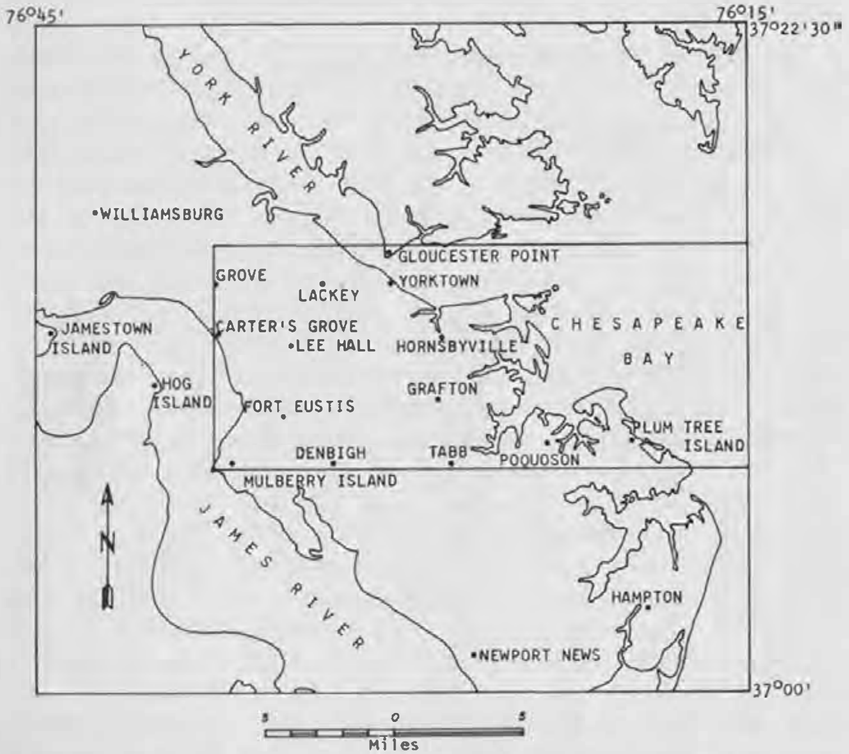

Figure 2. Index map of lower York-James Peninsula showing localities cited in text (mapped area encompassed by outline).

tion in the Poquoson, Tabb, Grafton, Seaford and Denbigh sections. Major surface routes include Interstate Highway 64, U.S. Highway 60, and State Highways 143 and 17 which have a southeast trend parallel to the length of the York-James Peninsula (Plates 1, 2). Numerous paved secondary roads crisscross the quadrangles. This part of the York-James Peninsula is served by the Chesapeake and Ohio Railway and by Patrick Henry Airport. Industrial facilities in this area produce electricity, petroleum products, textile fibers, and other manufactured goods.

During the Revolutionary War, Yorktown was the site of a major American and French siege that resulted in the surrender of Cornwallis and his army, a defeat that effectively terminated the war. The Colonial National Historical Park was established to depict the events of the Revolutionary War to the public (Plates 1, 2).

The part of the York-James Peninsula covered by the Yorktown, Poquoson West, and Poquoson East quadrangles is drained by the York, James, and Poquoson rivers, their tributaries, and several small creeks, all of which flow generally eastward into Chesapeake Bay (Plates 1, 2, 3). The drainage divide between the York and James rivers is within one or two miles of the York River. As a consequence, the tributaries to the York River, Felgates, Ballard, Yorktown, and Wormley creeks, are short and drain only a narrow strip of land along the north side of the York-James Peninsula. Skiffes Creek and Warwick River, which flow southward, empty into the James and drain the major portion of the Yorktown quadrangle. Back Creek, Chisman Creek, Poquoson River, and Bennett Creek flow into Chesapeake Bay and drain the eastern part of the study area. Harwoods Mill Reservoir, City Reservoir, and Skiffes Creek Reservoir, formed by the damming of the Poquoson River, Warwick River, and Skiffes Creek, respectively, serve as water supplies for the City of Newport News and surrounding areas and for the various military installations. The tributaries to the master streams are tidal and have extensive salt and freshwater marshes along their lower reaches. Salt marshes cover much of the Poquoson East quadrangle. Chesapeake Bay occupies a major portion of the Poquoson East quadrangle and the northeastern portion of the Poquoson West quadrangle. It is less than 18 feet deep over the Drum Island Flats, Poquoson Flats, and York Spit. An extension of the York River channel, part of which has been dredged, crosses the Poquoson East quadrangle from the northwest to the central east portion. Erosion along the Bay and along the York and James rivers has been severe locally and the banks have been protected by rip-rap groins and other man-made erosion control structures.

Field work in the Yorktown, Poquoson West and Poquoson East quadrangles was carried on intermittently from June 1968 to October 1971 by the author. Subsurface data were obtained from 22 test holes, which were drilled under contract let by the Virginia Division of Mineral Resources (Table 1), from 158 engineering borings and from 93 hand auger holes. The locations of the test holes and selected engineering borings and outcrops are shown on Plates 1, 2 and 3. Split-spoon samples were ob-

Table 1. Summary of data from test holes: alluvium, al; Norfolk Formation, Qn; Windsor Formation, Qw; and Yorktown Formation, Ty (Elevation in feet.)

Drill Hole	Quadrangle Location	Top of Hole	Top of Formation				Bottom of Hole	Owner
			al	Qn	Qw	Ty		
W-2583	Yorktown	61.0			61.0	34.0	—10.0	State
W-2584	Yorktown	91.0			91.0	64.0	10.0	U. S. Navy
W-2585	Yorktown	82.0			82.0	50.5	1.0	U. S. Navy
W-2586	Yorktown	90.0			90.0	45.0	9.0	U. S. Navy
W-2587	Yorktown	78.0			78.0	41.0	— 3.0	R. M. Redcross
W-2588	Yorktown	63.0			63.0	25.0	—13.0	Nat. Park Service
W-2589	Yorktown	56.0			56.0	38.0	— 9.0	Nat. Park Service
W-2590	Poquoson West	56.0			56.0	21.0	—15.0	State
W-2591	Poquoson West	12.0		12.0		2.0	—38.0	State
W-2592	Poquoson West	8.0		8.0		— 4.0	—37.0	S. A. Stroud
W-2593	Poquoson West	4.0		4.0		— 8.0	—41.0	State
W-2594	Yorktown	8.0	8.0			0.0	—52.0	Nat. Park Service
W-2595	Yorktown	44.0		44.0	40.0	29.0	17.0	State
W-2596	Yorktown	32.0		32.0		—11.0	—28.0	H. E. Holzbach
W-2597	Yorktown	35.0		35.0		—19.0	—25.0	State
W-2598	Yorktown	36.0		36.0		14.0	—14.0	State
W-2599	Poquoson West	49.0		49.0		22.5	—17.0	State
W-2600	Poquoson West	56.0			56.0	29.0	—10.0	State
W-2601	Poquoson West	8.0		8.0		1.0	—37.0	State
W-2602	Poquoson West	49.0			49.0	26.0	—12.0	State
W-2603	Poquoson West	32.0		32.0		21.0	—23.0	F. A. Combs
W-2604	Poquoson West	9.0		9.0		1.0	—36.0	Emmaus Church

tained from the test holes at five-foot intervals. The subsurface data were supplemented by information from 137 natural and man-made outcrops. Wherever possible, representative fossil collections were obtained from each major lithofacies of the Yorktown Formation (Appendix II).

The author wishes to thank Dr. N. K. Coch, Department of Earth and Environmental Sciences, Queens College, New York, and Dr. K. F. Bick, Department of Geology, College of William and Mary, for their assistance in the field investigations and provocative discussion of stratigraphic problems. The writer also gratefully acknowledges the financial and technical assistance provided by Dr. James L. Calver, Commissioner of Mineral Resources and State Geologist. Messrs. O. D. Zook, R. L. Brandt, G. S. Forrest, and many other local citizens permitted the author access to their lands and borrow pits. Mr. James Corson of the U. S. National Park Service, Captain W. J. Maddocks of the U. S. Naval Weapons Station at Yorktown, and Mr. William Fyfe of the Post Engineers, Fort Eustis permitted drilling and geologic field work on federal lands or provided drilling records. Messrs. Page Herbert and James Melchor, of Herbert & Associates, Virginia Beach, and Thomas Rogers of Virginia Electric and Power Company, Richmond, provided engineering and drilling logs from many sites within the study area. Mesdames M. E. Magary and M. A. Johnson assisted in the preparation of the manuscript and illustrations.

MORPHOLOGY

The topography of the lower York-James Peninsula portion of the Coastal Plain in Virginia is characterized by a succession of plains (Figure 3) whose surfaces dip gently eastward or toward the major estuaries. The plains are separated from one another by scarps that face eastward or parallel the York and James rivers. Earlier workers (Clark and Miller, 1912; Wentworth, 1930; Roberts, 1932; and others) applied the term terrace to those plains (Table 2). Subsequently, the terrace names were also applied to stratigraphic units that were thought to be coextensive with the terraces. A concise review of the problems of terrace morphology and stratigraphy in southeastern Virginia was presented by Coch (1965). Because of the ambiguous use of the term terrace, the terms plain and flat are applied to these planar geomorphic features in this report.

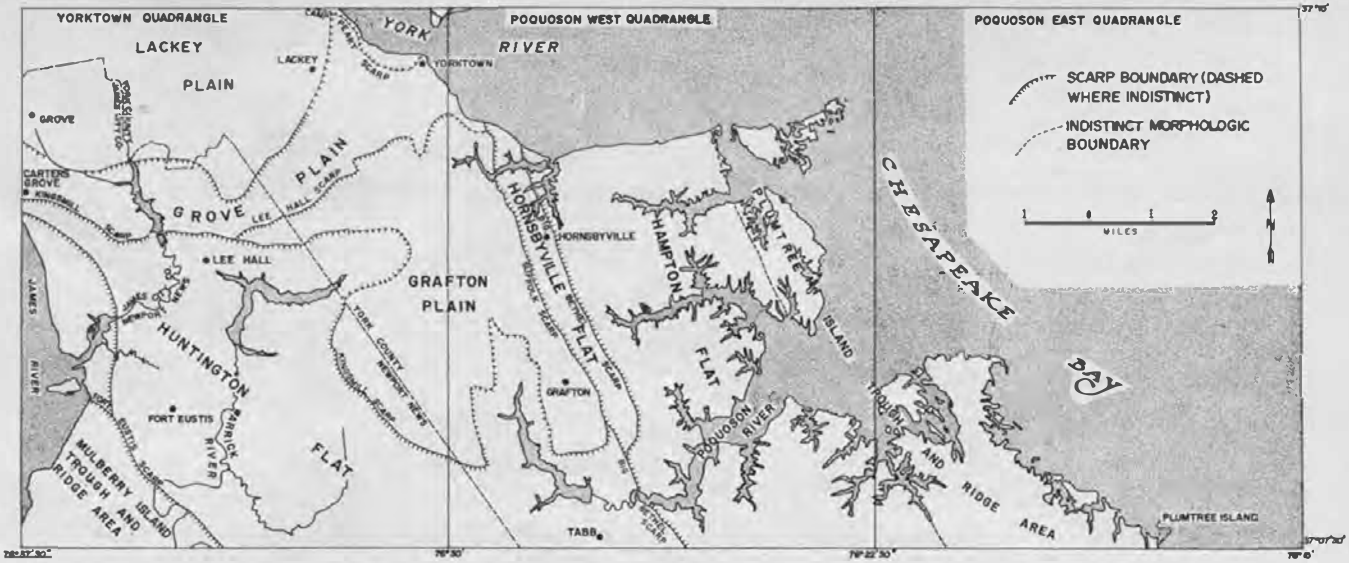

Figure 3. Map showing the principal geomorphic features in the Yorktown, Poquoson West, and Poquoson East quadrangles.

Table 2. Morphologic features recognized by various workers.

CLARK AND MILLER (1912)	WENTWORTH (1930); ROBERTS (1932)	COOKE (1931)	BICK AND COCH (1969)	JOHNSON (1969)	THIS REPORT	
					JAMES RIVER	CENTRAL YORK - JAMES PENINSULA
	SURRY SCARP	SURRY SCARP	SURRY SCARP	SURRY SCARP	SURRY SCARP (90'-120')	
		WICOMICO TERRACE	90-FOOT PLAIN (80'-90')	90-FOOT PLAIN	LACKEY PLAIN (80'-90')	
					UNNAMED SCARP	
WICOMICO TERRACE	WICOMICO TERRACE (60'-90')		70-FOOT PLAIN (55'-70')	70-FOOT PLAIN	GROVE PLAIN (70'-75')	
					LEE HALL SCARP (58'-72')	
		PENHOLOWAY TERRACE			GRAFTON PLAIN (48'-60')	
	SUFFOLK SCARP	SUFFOLK SCARP	SUFFOLK SCARP	SUFFOLK SCARP	KINGSMILL SCARP (40'-65')	SUFFOLK SCARP (25'-60')
TALBOT TERRACE	CHOWAN TERRACE (25'-45')	TALBOT TERRACE	45-FOOT PLAIN	45-FOOT PLAIN 30-FOOT PLAIN	HUNTINGTON FLAT (30'-45')	HORNSBYVILLE FLAT (25'-30')
				BIG BETHEL SCARP	FORT EUSTIS SCARP (10'-30')	BIG BETHEL SCARP (18'-31')
	DISMAL SWAMP TERRACE (10'-25')	DISMAL SWAMP TERRACE		15-FOOT PLAIN	HAMPTON FLAT (5'-18')	
	PRINCESS ANNE TERRACE (0'-15')	PRINCESS ANNE TERRACE			MULBERRY ISLAND TROUGH AND RIDGE	PLUMTREE ISLAND TROUGH AND RIDGE

Plains and scarps in the study area (Figure 3, Table 2) are traceable into adjoining areas. These plains and scarps represent complex depositional and erosional features. The Lackey plain, the 90-foot plain of Bick and Coch (1969) and the upper part of Isle of Wight plain of Coch (1965, 1968), extends from the toe of the Surry scarp in the Williamsburg area to the vicinity of Lackey (Figure 3). The plain is at an elevation of approximately 90 feet near the scarp, slopes gently to the southeast at less than one foot per mile, and is 80 feet above sea level 0.5 mile southeast of Lackey. The plain has been extensively dissected by the tributaries to Skiffes and Felgates creeks. It is separated from the next lower plain, the Grove plain, by an indistinct scarp that parallels the east-west segment of Skiffes Creek, extends eastward to a point about one mile northeast of Lee Hall, and then trends northeastward to the east side of the U. S. Naval Weapons Station. The Lackey plain is directly underlain by the Windsor Formation.

The Grove plain extends from an area just south of Grove, where it has an elevation of 72 feet, southeastward in an arcuate form to the vicinity of Rochambeau Village and then trends northeastward to Yorktown (Figure 3). The plain is 0.5 mile wide near Grove, is about one mile wide to the northeast, and has been dissected by Skiffes Creek and Baptist and Great runs. No apparent regional dip has been observed on the Grove plain as elevations on the surface rarely exceed 75 feet and are not below 70 feet except where the plain has been dissected. The Grove plain is bounded on the south by the Kingsmill scarp, on the southeast by the Lee Hall scarp, and on the northeast by the Camp Peary scarp. It is equivalent to the 70-foot plain of Bick and Coch (1969) and to the middle part of the Isle of Wight plain of Coch (1968) and is directly underlain by the Windsor Formation.

The Lee Hall scarp, named for the village of Lee Hall, trends in a nearly straight line northeast across the northeast quarter of the Yorktown quadrangle to the vicinity of Yorktown where it curves to the east (Figure 3). The scarp separates the Grove plain from the next lower Grafton plain. It ranges in elevation from 58 feet at the toe of the scarp to about 72 feet near its crest. The Lee Hall scarp is truncated by the Kingsmill scarp to the southwest, and becomes unrecognizable in the Marlbank area to the east because of the dissection along West Branch.

The Grafton plain covers the central portion of the map area (Figure 3). The elevation of this relatively undissected plain ranges between 48 and 60 feet. Although the plain appears to dip gently toward the east at approximately one foot per mile in the western part, the plain is remarkably flat in the eastern part and is at 55 feet nearly everywhere. Major re-entrants caused by erosion occur on the southside of the Grafton plain along Beaverdam Creek and above Harwoods Mill Reservoir. The Grafton plain is bounded on the northwest by the Lee Hall scarp, on the east by the Suffolk scarp and on the south by the Kingsmill scarp. Its surface is relatively flat and poorly drained; numerous small ponds and marshes are present southeast of Harris Grove (Plate 2). The plain comprises the lower part of the Isle of Wight plain of Coch (1965, 1968) and is underlain by the Windsor Formation.

The Kingsmill scarp, named by Bick and Coch (1969), extends from the Carters Grove area southeastward to Harwoods Mill Reservoir (Figure 3). The scarp is the estuarine equivalent of the Suffolk and is comparable to the Camp Peary scarp along the York River. The toe of the scarp ranges in elevation from 40 to 45 feet and the crest of the scarp is 65 feet in the Carters Grove area. East of Lee Hall the crest of the scarp is at the level of the Grafton plain. A short segment of the Camp Peary scarp (Bick and Coch, 1969) extends from Yorktown Creek northwestward onto the U. S. Naval Weapons Station (Figure 3). The toe of the scarp lies at approximately 50 feet and crests at 70 feet. Both scarps were formed by erosion of the Windsor Formation by the estuarine James and York during Norfolk time.

The Suffolk scarp (Wentworth, 1930, p. 63) trends southeastward across the Poquoson West quadrangle (Figure 3). This scarp is the most prominent scarp on the York-James Peninsula (Figure 3); it rises from an elevation of 25 to 30 feet near its toe to nearly 60 feet at its crest in less than 0.2 mile (Figure 4). The scarp was formed by wave and current erosion along a mainland beach during Norfolk time. Along the Suffolk scarp the Windsor Formation was eroded and then veneered with beach and near-shore sediments of the Norfolk Formation. The Suffolk scarp separates the Grafton plain from the narrow Hornsbyville flat.

The Hornsbyville flat is approximately 0.5 mile wide and extends from the York River on the north to within 0.75 mile of

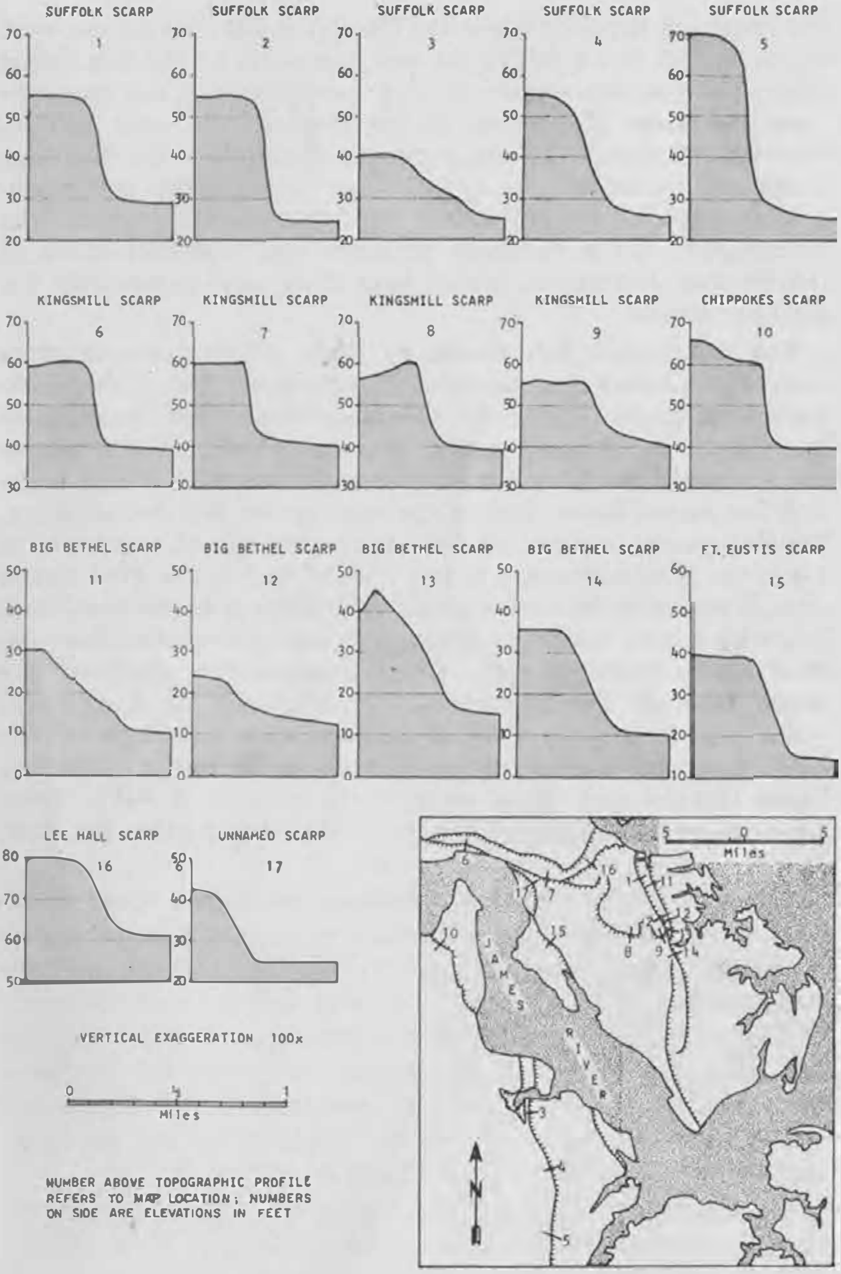

Figure 4. Topographic profiles of scarps on the lower York-James Peninsula and south of the James River.

the Poquoson River (Figure 3). The flat is bounded on the west by the Suffolk scarp and on the east and south by the Big Bethel scarp. The flat slopes eastward and southward and has its maximum elevations at 30 feet in the Hornsbyville area and its lowest point near its southern margin. Except for the Wormley Creek area, dissection of the flat has been limited and consequently much of the surface of the flat is poorly drained. The Hornsbyville flat is underlain by beach and nearshore sands of the Norfolk Formation, which have been used extensively for sand and gravel.

The Huntington flat, named by Coch (1971), extends from the Carters Grove area southeast to the lower end of the York-James Peninsula (Figure 3). Bick and Coch (1969) referred to this flat as the 45-foot plain. It is bounded on the northeast by the Kingsmill scarp, on the southwest by the Fort Eustis scarp and the James River, and on the east by the Big Bethel scarp. The flat ranges in elevation from approximately 45 feet near the toe of the Kingsmill scarp to less than 30 feet in the Fort Eustis area. It slopes to the southeast at 0.5 foot per mile. Skiffes Creek, Warwick River, Poquoson River, and their tributaries have extensively dissected the plain. Large tracts of the interfluves are poorly drained. The Huntington flat (Plates 1, 2) is aggradational and is underlain by fluvial-estuarine sediments of the Norfolk Formation. A series of low southwestward-trending linear troughs and ridges occur in the vicinity of Tabb. These features merge imperceptibly with the Huntington flat near Tabb.

The Fort Eustis scarp extends from the James River southeast across the Fort Eustis Military Reservation to the mouth of the Warwick River (Figure 3). Millstead Creek and the lower portion of Warwick River flow along the toe of the scarp. The toe of the scarp is at 10 feet and the crest at nearly 30 feet. The scarp separates the Huntington flat from the Mulberry Island trough and ridge area. It was initially cut during late Norfolk time by the erosion of the James River and steepened recently by bank erosion along the Warwick River.

Johnson (1969) named the low scarp that trends north-south through the settlement of Big Bethel in Newport News the Big Bethel scarp. The northern extension of this scarp crosses the Poquoson West quadrangle from southeast to northwest (Figure 3). In this area, the Big Bethel scarp separates the Hampton flat and Hornsbyville flat. The scarp rises from an elevation of 16 feet at the toe to a maximum of 31 feet locally at the crest over a distance of less than 0.1 mile. The Big Bethel scarp is cut into the sand facies of the Norfolk Formation north of Grafton Bethel School (Plate 2) and into its clayey-sand facies south of this point.

The Hampton flat, named by Coch (1971) for the City of Hampton, occupies the area between the Big Bethel scarp and the Plumtree Island trough and ridge area along Chesapeake Bay (Figure 3). The Hampton flat (Plates 2, 3) consists of Goodwin Neck, the western portion of Crab Neck, Fish Neck, and the vicinity of Poquoson. It ranges in elevation from 5 to 18 feet and slopes toward the Chesapeake Bay at 5.0 feet per mile. This flat is drained by Back and Chisman creeks, Poquoson River, and several smaller creeks and the interfluvial areas are flat and poorly drained. The sandy-clay facies of the Norfolk Formation underlies the flat (Plates 2, 3).

The troughs and ridges on Goodwin Islands, Crab Neck, and Plumtree Island are here named the Plumtree Island trough and ridge area (Plate 2). This area consists of nearly parallel, linear ridges of sand and intervening troughs occupied by tidal marshes or mud flats. The sand ridges trend N. 45° W. in the Plumtree Island area to N. 30° W. in the Goodwin Islands-Crab Neck area. The ridges, varying in length from a few hundred feet to nearly a mile, are 3 to 6 feet above the adjacent troughs. The ridges may be vegetated with salt grasses or trees, depending upon the topographic and local soil conditions. The sand ridges are underlain by the silty-sand facies of the Norfolk Formation. Locally, Holocene beach and dune sands cover the ridges. At Tue and Bay Tree points (Plate 2) the sand ridges are being extensively eroded.

The Mulberry Island trough and ridge area, which is here named for Mulberry Island on the James River (Plate 2), consists of short, subparallel ridges covered by trees and intervening troughs with marsh grass. The ridge trends N. 45° W. and rise 4 to 6 feet above the low-lying marshes. The maximum elevation of the ridge is about 10 feet. Small tidal creeks, or guts, drain this area. Jamestown Island, Hog Island, and Ragged Island have trough and ridge topography similar to Mulberry Island. A small patch of dunes occurs between Morley Gut and Blow Creek.

STRUCTURE

The area investigated lies along the southeastern margin of the Chesapeake-Delaware Embayment (Murray, 1961). The regional dip of the late Tertiary rocks is toward the southeast at 2 to 7 feet per mile. From an examination of beds in the lower Yorktown Formation along the right bank of the York River and on both sides of the James River west of the study area, the depositional strike ranges from N. 18°E. to N. 45°E. having changed as the Yorktown was deposited.

In the bluffs southeast of Yorktown, Virginia, the beds in the silty sand, shelly sand, cross-bedded coquina, and coquina facies dip toward the northwest at 8 to 55 feet per mile. This reversal of dip was observed by Stephenson, Cooke, and Mansfield (1933) who considered it a result of tectonic warping. The angle of dip decreases on successive beds within the cross-bedded coquina facies and the overlying coquina facies bedding is almost horizontal. The warping was contemporaneous with Miocene deposition and appears to be a result of differential compaction of underlying beds in response to loading by the growing cross-bedded coquina facies of the Yorktown Formation. This would account for the decrease in dips on beds in the coquina facies. All tilting of the Yorktown beds had ceased before the Pleistocene because the overlying Windsor Formation does not exhibit the reversal of dip observed in the Yorktown.

STRATIGRAPHY

Deposits ranging in age from late Miocene to Holocene are exposed in the Yorktown, Poquoson West, and Poquoson East quadrangles. The Yorktown Formation, the uppermost formation in the Chesapeake Group, crops out along the York River and its tributaries and in many man-made excavations in the central part of the study area. The overlying Sedley and Bacons Castle formations that occur to the west are not present. The Windsor Formation rests unconformably upon the Yorktown Formation and constitutes the principal exposed strata in the western part of the study area (Plates 1, 2). The Norfolk Formation of late Pleistocene age crops out along the James River and over most of the Poquoson West and Poquoson East quadrangles (Plates 2, 3). Sediments of this formation overlie the Windsor and Yorktown formations disconformably. Holocene deposits occur along the shores of Chesapeake Bay and along major streams and estuaries.

MIOCENE SERIES

Yorktown Formation

Lyell (1845), Rogers (1884), and several early paleontologists conducted pioneer studies of the deposits and fossils exposed in the bluffs along the lower York-James Peninsula. However, it was not until 1906 that Clark and Miller formally applied the name Yorktown Formation to the sequence of shelly sands and clays along the York River near Yorktown. The Yorktown Formation ranges in thickness from 0 at the Fall Zone to over 500 feet at the lower end of the York-James Peninsula (Gibson, 1970), but the maximum thickness measured in the study area was 60 feet. Paleotopography of the Yorktown is illustrated in Figure 5.

Detailed stratigraphic studies of the Yorktown Formation were made by Mansfield (1943) who subdivided the Yorktown into two faunal zones. They are:

Zone 2: *Turritella alticostata zone*
  Upper part—beds at Suffolk
  Middle part—beds ("a" through "f") at Yorktown
  Lower part—*Chama*-bearing bed
Zone 1: *Pecten clintonius zone*

Although the Yorktown Formation is abundantly fossiliferous, it has been difficult to resolve the question of its precise age. The Yorktown has long been considered late Miocene in age. In a study of the Tertiary Noetinae, MacNeil (1938) concluded that the *Chama*-bearing beds of the Yorktown Formation were late Miocene in age. Mansfield (1943) supported this view with further stratigraphic and paleontologic evidence. Yorktown whales (U. S. Geological Survey, 1965) appear well advanced over those in the St. Marys Formation and suggest that the upper Yorktown might be early Pliocene in age.

In this study the Yorktown Formation has been subdivided into six facies based upon the texture, composition, and bedding features of each unit. The uppermost portion of the Yorktown is weathered; structure and mineral composition reflect the content of some of the facies (Figure 6).

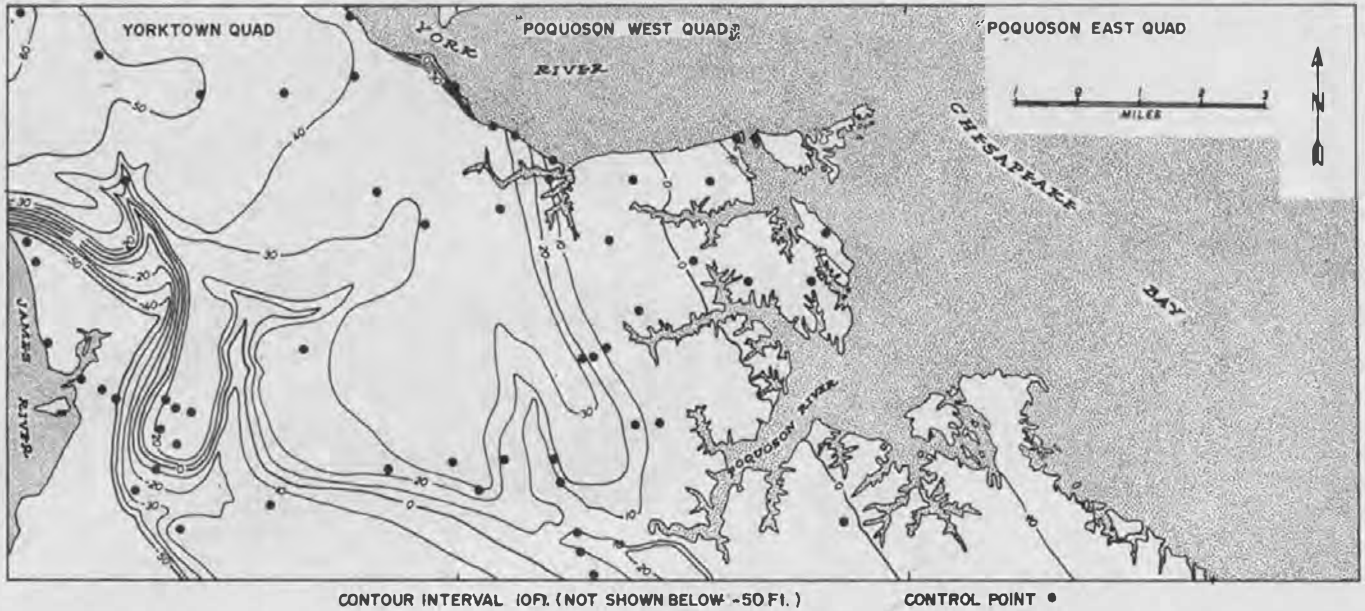

Figure 5. Paleotopography on the top of the Yorktown Formation in the Yorktown, Poquoson West, and Poquoson East quadrangles.

Silty-sand facies: The silty-sand facies crops out on the beach below the U. S. Coast Guard Reserve Training Center along the York River (Plate 2), in drainage ditches near Poquoson, and in borrow pits southeast of Grafton (Appendix I, Section A; Figure 7). This facies of the Yorktown corresponds to beds "a" and "b" (Zone 2) of Mansfield (1943) and the lower clay member of Roberts (1932). The facies extends from the Yorktown area east to the end of the York-James Peninsula and is more than 50 feet thick in the Poquoson area. The silty-sand facies grades upward into the shelly-sand facies in the Yorktown area (Figure 6) and east of the Suffolk scarp it is overlain by the Norfolk Formation.

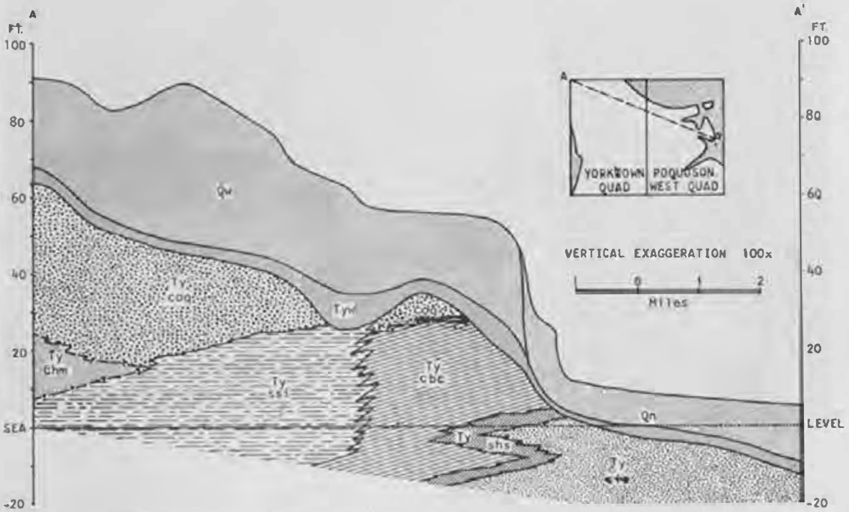

Figure 6. Schematic cross-section showing the relationship between the lithofacies of the Yorktown Formation in the Yorktown and Poquoson West quadrangles: Norfolk Formation, Qn. Windsor Formation, Qw. Yorktown Formation, Ty—weathered zone, w; silty sand facies, sis; shelly sand facies, shs; cross-bedded coquina facies, cbc; coquina facies, coq; sandy silt facies, ssi; and *Chama* facies, chm.

This facies is composed of bluish-gray to greenish-gray fine sand and intercalated clayey silt. Bedding is massive, but locally laminated to thick-bedded sediments occur in the sequence. Scour and fill structures are common. The silty-sand contains an abundance of burrows and bioturbation of the sediments has

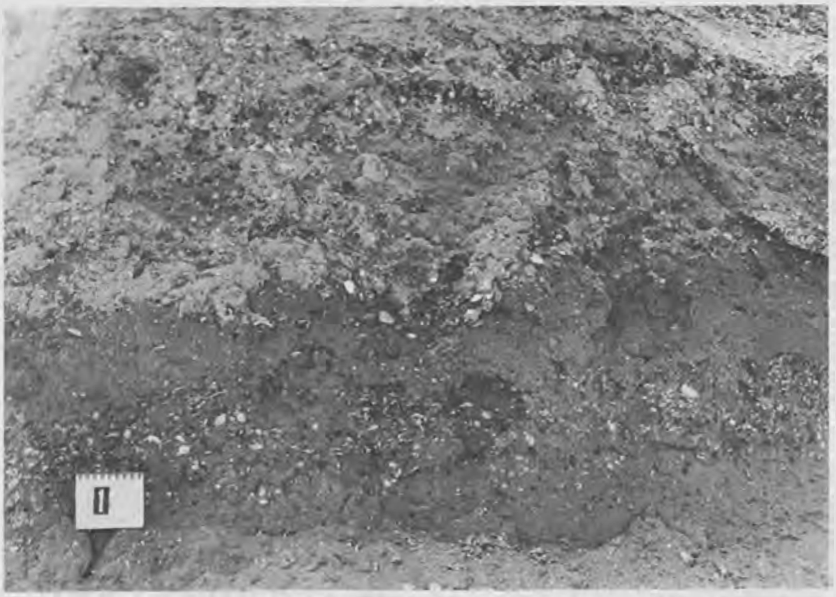

Figure 7. Silty-sand facies of the Yorktown Formation in Brandt pit one mile southeast of Grafton. The silty-sand facies is fossiliferous and contains a zone of *Crepidula fornicata*. An abundantly fossiliferous zone is pictured above scale.

obscured or destroyed bedding planes in many places. Quartz grains and whole and broken calcareous fossils constitute the major components of the sediment. Minor amounts of clay, heavy mineral, and phosphatic bone material are also present. Small lenses of biofragmental sand were encountered in bore holes in the vicinity of Poquoson. There is considerable lateral variation in the quantity of shell material, and the carbonate content and grain size increase upward in the facies. Weathering of the silty sand leaves a soft, gray clayey sand residue mottled yellowish to reddish brown.

The silty-sand facies contains a diverse, well-preserved invertebrate fauna composed of mollusks, bryozoans, barnacles, foraminifera, ostracodes, corals, hydrozoans, echinoids, and trace fossils of worms and sponges (Appendix II, faunal assemblages A, B, C). *Turritella, Crepidula,* and cheilostomatous bryozoans are the most abundant macrofossils in the western outcrop area of the facies. These taxa decrease in relative abundance in the fauna eastward as the bivalves assume greater importance in the fauna. Locally, the silty-sand facies contains undisturbed colonies of *Crepidula, Ostrea, Dosinia, Ensis, Mercenaria* and *Yoldia;* all but *Crepidula* and *Ostrea* are burrowing forms. Although a majority of the bivalves are found disarticulated, the shells are usually whole and exhibit little or no evidence of abrasion. In addition to the invertebrate fossils, fish and aquatic mammal remains are common. These include shark's teeth and vertebrae of fish, porpoises, and whales.

The stratigraphic relationship of the silty-sand facies to contiguous facies, its textural, mineralogic, and sedimentary features, and its fauna suggest that this facies was laid down in an offshore marine environment in water 50 to 125 feet deep. Brackish water influence was limited to the western part of the area. The general increase in grain size, carbonate content, number of fossils, and species diversity upward in the facies indicate shallowing of the sea during the deposition of this unit.

Shelly-sand facies: The shelly-sand facies crops out along the south bank of the York River in the vicinity of Moore House (Plate 2) and is encountered in the subsurface to the west of this area. This facies grades westward into the cross-bedded coquina facies and eastward into the silty-sand facies (Figure 6). The maximum measured thickness of this facies is about 8 feet in the map area. The shelly-sand facies corresponds in part to beds "c" and "d" (Zone 2) of Mansfield (1943) and the more fossiliferous part of the clay member of Roberts (1932). This facies is intermediate in character between the silty-sand and coquina facies.

The dominant sediment type is a bluish-gray, calcareous and quartzose sand, in places somewhat clayey, with abundant whole and broken shell (Figure 8). The latter usually constitutes less than 30 percent of the sediment. Bedding is lacking although horizontal shell material gives the appearance of rudimentary stratification in places; scour and fill structures are common. Most of the bivalves have been disarticulated by waves or currents. Deep-burrowing mollusks, such as *Panope*, are usually found with the valves articulated and in their original life positions; locally, assemblages of *Crepidula* are prominent. Wave action appears to have been of low intensity because the shells, although displaced, rarely show the effects of abrasion or contemporaneous fragmentation. Many shells with delicate ornamentation retain these structures without significant damage.

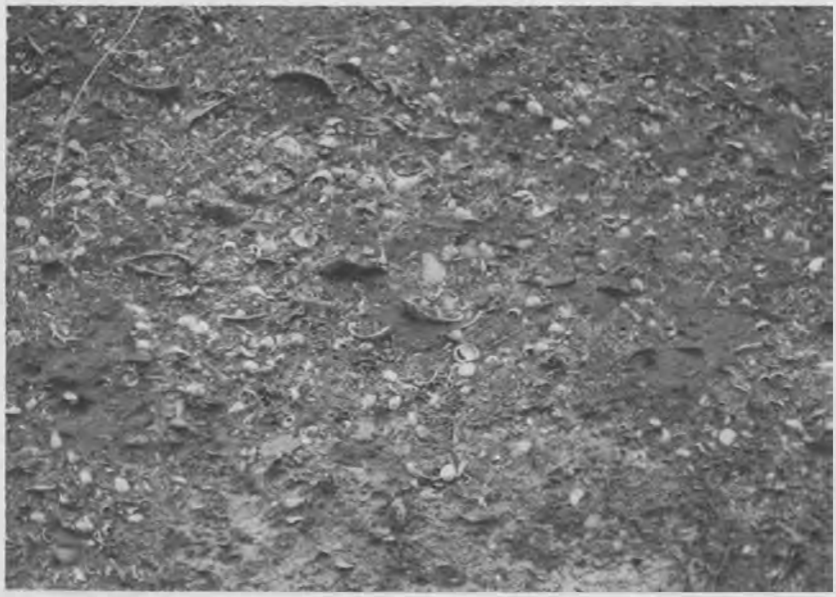

Figure 8. Shelly-sand facies of the Yorktown Formation along York River near Moore House (Plate 2). The shelly-sand facies is massively bedded, abundantly fossiliferous, and the fossils are grain supported.

Much of the breakage of shells in the facies has resulted from post-depositional compaction.

The fauna in the shelly-sand facies is diverse (Appendix II, faunal assemblage D) and representatives of the pelecypods and gastropods are most conspicuous. Lesser numbers of scaphopods, corals, worms, echinoids, bryozoans, and barnacles are present. The fauna of the shelly-sand facies lacks a well-developed encrusting component, such as the corals and bryozoans, in contrast to the western part of the silty-sand facies. Shells in the shelly-sand facies tend to be more robust and include a greater number of clinging suspension feeders than does the adjacent silty-sand facies. These shells are also less fragmented and abraded by wave and current action than those in the cross-bedded coquina facies.

Cross-bedded coquina facies: The cross-bedded facies is exposed discontinuously in the bluffs along the south bank of the York River between the Coleman Memorial Bridge (Plate 1) and the U. S. Coast Guard Reserve Training Center (Plate 2). Smaller outcrops occur along West Branch and Wormley Creek and in abandoned pits in the Marlbank area (Appendix I, Section B). Presumably Cornwallis occupied a cave during the Siege of Yorktown, now known as Cornwallis Cave (Figure 9), carved out of this facies. Similar deposits have been encountered in bore holes to the southwest within the Colonial National Historical Park and in large extraction pits in the Chuckatuck area (Rogers, 1884; Bowman and others, 1968). This facies is composed of biofragmental sand and is set apart from other facies of the Yorktown by exceptionally large-scale cross-stratification. The cross-bed sets range in thickness from about 3 feet in the Marlbank to more than 15 feet in the Cornwallis Cave area. West of Point of Rocks (Plate 2) the cross-beds have a dip of about 26 degrees toward the northwest (strike N. 38°E. to N.

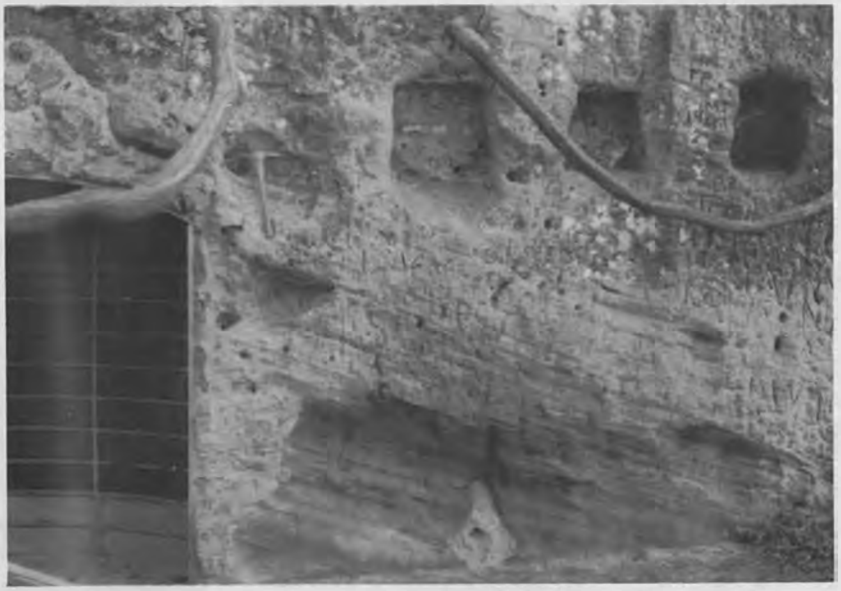

Figure 9. Cross-beds in the cross-bedded coquina facies at Cornwallis Cave, Yorktown. The cross-beds consist of biofragmental sands and dip to the northwest at 24 degrees. Note the vertical decapod burrow over the entrance to the cave. The cave was carved out by man and was presumably used by Cornwallis during the Siege of Yorktown.

63°E.) ; southeast of this point, dip directions are more variable and dips are mainly to the northeast, averaging 22 degrees (strike N. 55°E. to N. 53°W.). The cross-bedded coquina facies intertongues with the silty-sand to the east and with the sandy-silt and coquina facies to the west, and grades downward into the shelly-sand facies (Figure 6). A thin remanent of the coquina facies caps the bevelled edge of the cross-bedded coquina. The maximum thickness of the cross-bedded facies in this area is approximately 35 feet.

The shell material is moderately to well-sorted, medium to coarse fragmental molluscan sand. Carbonate content in this facies ranges from 56 to 91 percent by weight; iron oxides, clay, and quartz are present. Planar shells and fragments are normally oriented nearly parallel to the dip plane of the cross-bed except where they have been disturbed by slumping of burrowing organisms. Although the sand is usually friable, carbonate-rich ground water and salt spray from the adjacent York River have cemented the sand into a coquinite (an indurated coquina) in places. In less exposed areas the coquina is altered to a spongy, tan to reddish-brown clayey silt. Fresh samples from well borings are a bluish gray.

The cross-bedded coquina facies contains relatively few undamaged shells or articulated bivalves. Mollusk shells are invariably abraded and/or broken. Recognizable remains of thirty-two genera of fossil mollusks have been identified from this facies. The most common fossils are *Mulinia*, *Crepidula*, *Pecten*, *Venericardia*, and *Glycymeris*. Decapod burrows, up to 1.5 inches in diameter and with knobby exterior ornamentation, commonly occur in their original vertical position. These burrows, similar in aspect to those formed by *Calianassa major*, cut across the individual cross-beds at an obtuse angle and terminate at bedding planes. The burrows are firmly cemented with calcite, siderite, and iron oxide. Current and wave action scoured the sediments from around some of the burrows, causing them to topple over.

The cross-bedded coquina was deposited as an offshore submarine bar in waters probably 5 to 25 feet deep. Shell material for the construction of the bar was derived from mollusks living on the east flank of the bar. Waves carried the shells landward across the bar, mascerating and rounding the shells as they moved. Shell material was carried completely across the bar into the lagoon on the west side of the bar. This process resulted in the formation of the steeply dipping northwest cross-beds.

Longshore currents transported some of the shell material northward along the bar. Some of this material spilled over into the lagoon but some was carried to the northeast and formed crossbeds with northeast dips. Fine shell debris was swept off the bar and into the lagoon.

Sandy-silt facies: The sandy-silt facies is exposed in the base of O. D. Zook pit (Plate 1; Appendix I, Section C) and in the base of the bluff along the York River below Stony Point. This facies consists of medium bluish-gray sandy silt with thin laminae of finely divided shell and fine to medium quartz sand. The sediments have been extensively burrowed and the burrows are filled with medium to coarse shell sand (Figure 10). The bedding planes, where preserved, are slightly undulatory. The carbonate content in this facies ranges from about 8 to 61 percent by weight; other constituents are quartz and clay. Upon weathering, the sediments become light gray in color and powdery. The facies grades upward into the coquina facies in less than one foot by progressive increase in the shell content of the sediment (Figure 6). The sandy-silt facies intertongues with the crossbedded facies to the east. The maximum thickness of the sandy silt facies measured in this area was 16 feet. This facies is sparsely fossiliferous. Locally, indigenous *Crepidula* and *Ostrea* abound and form isolated colonies. Scattered shells of infaunal and vagrant benthonic mollusks are preserved with only limited evidence of abrasion or breakage.

Coquina facies: The coquina facies crops out along the south bank of the York River between the U. S. Naval Weapons Station (Plate 1) and the U. S. Coast Guard Reserve Training Center (Plate 2) where it forms a ledge in places near the top of the bluff. Other important exposures occur along State Highway 17 about 0.25 mile south of the Coleman Memorial Bridge (Plate 2) and in O. D. Zook pit (Plate 1; Figure 11). The coquina facies overlies the sandy-silt facies and grades laterally into the cross-bedded coquina facies, and, questionably, the *Chama* facies (Figure 6). Sediments assigned to this facies have been recovered from drill holes (W-2584 through W-2587) across the northern half of the Yorktown quadrangle and from exposures along the right bank of the James River.

The coquina facies is composed of whole and broken shells with a fine to coarse-grained biofragmental sand filling the interstices between the shell material. The carbonate composition varies from 47 to 89 percent by weight; the other constituents

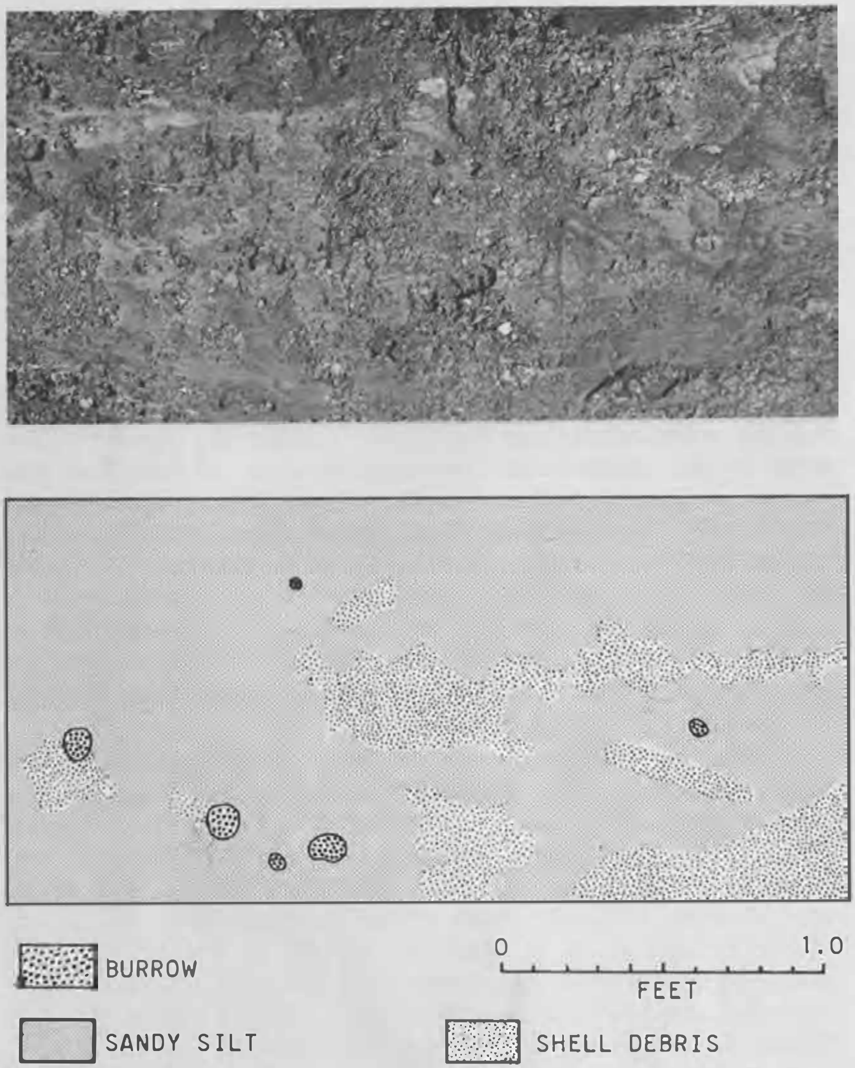

Figure 10. Sandy-silt facies of the Yorktown Formation at the base of O.D. Zook pit, is approximately one mile southwest of Yorktown on State Highway 238. The sediment is extensively burrowed and composed of interbedded thin to thick beds of sandy silt and thin beds of broken, medium to fine, shell sand. Burrows are filled with medium to coarse shell sand and appear as irregular, rough-textured areas. (Diagram is illustration of location of components).

are quartz, clays, and iron oxides. Thick sequences of shells have poorly developed bedding. Biostromes of *Ostrea* (1 to 3 feet thick) within the sequence give the appearance of rudimentary bedding. In the eastern outcrop area (Plate 1) of the facies the proportion of biofragmental sand increases and the shells are grain supported. Additionally, bedding becomes more distinctive and the degree of sorting increases; also fragmentation of shell material is greater, faunal diversity decreases, and orientation of shell material is more pronounced. Current-oriented shells in the Marlbank area are commonly imbricated. A majority of *Mercenaria, Pecten, Ostrea,* and *Glycymeris* in these areas have the convex side of their shell oriented upward.

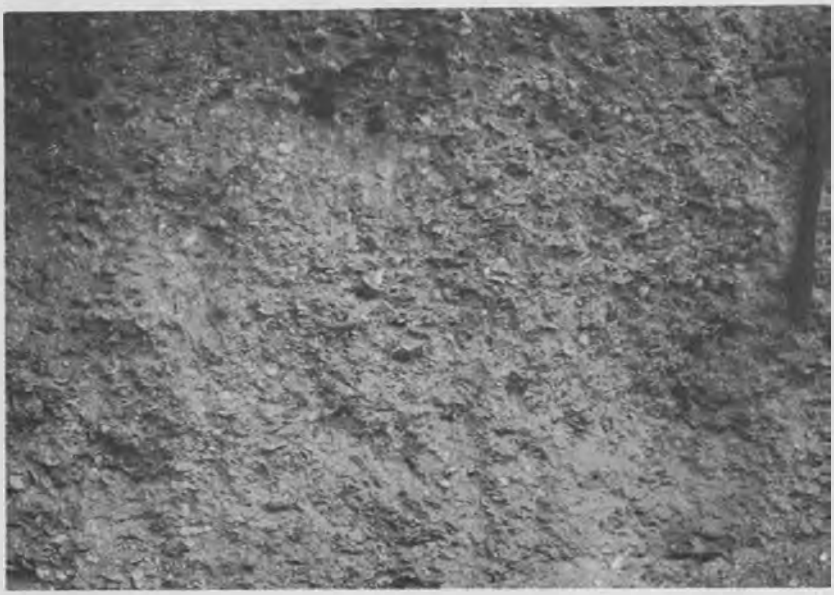

Figure 11. The coquina facies of the Yorktown Formation at O.D. Zook pit, is approximately one mile southwest of Yorktown on State Highway 238. Most of the sediment is composed of whole and broken shell.

The fauna in the coquina facies exhibits marked lateral and vertical variation. Changes in fauna may occur in the same bed over twenty to thirty feet or over two to three miles. Localized communities of *Ostrea, Pseudochama, Chama,* or other sessile benthonic organisms dotted the sea floor in the northern part of the Yorktown quadrangle during the time of deposition of the coquina facies (Appendix II, faunal assemblage E). These communities, each dominated by a single species, afforded protection, feeding grounds, and substrates for attachments of sessile species. Encrusting corals and bryozoans are uncommon in this facies, especially in the eastern part of the outcrop area. Solitary worms of the genera *Spirorbis* and *Polydora,* and boring clams and sponges are ubiquitous and constitute important elements in the epifauna. *Mercenaria, Panope, Eucrassetella, Dosinia* and *Ensis* are commonly found in their original life position. Southeast of Yorktown, the fauna in the coquina facies tends to be less diverse and exhibits more evidence of physcial damage.

Chama facies: The *Chama* facies does not crop out in the map area but sediments similar to those described by Johnson (1969) from the nearby Carters Grove area were encountered in drill hole W-2584 (Plate 1). Although the sediments recovered by the split-spoon samples from this hole were crushed and bedding characteristics were distorted, the abundant *Chama* remains in a biofragmental sand are indicative of this facies. The carbonate content of samples ranged from 38 percent to 81 percent. The facies grades eastward into the sandy-silt and coquina facies.

Weathered zone: Weathering of the upper Yorktown Formation has produced a variety of secondary features and minerals (Appendix I, Sections A-C). The composition and structure of the weathered products vary with the composition of the original sediment, the local ground water conditions, the vegetation in the area, the thickness and nature of the post-Yorktown deposits, and, in some cases, the proximity to an estuary. East of the Suffolk scarp, a thin veneer of Norfolk sediments was deposited on the eroded surface of the Yorktown Formation. In places the thin cover of Norfolk sands and the underlying silty-sand sediments of the Yorktown Formation are weathered. These sediments are a soft, light-gray, clayey sand mottled with yellowish-brown spots; leaching of the carbonates and the accompanying compaction results in subsidence of the overlying beds. Subsidence, probably less than a foot, has been limited on the Hampton flat and on the Hornsbyville flat because the depth of weathering of the Yorktown Formation is no more than three feet at the maximum. Compaction of the residue tends to accentuate the minor difference in the original mineral composition, producing a rudimentary bedding.

In places where the post-Yorktown cover is thinner, such as on slopes into valleys, weathering of more calcareous Yorktown sediments (cross-bedded coquina or coquina facies) creates an undulatory topography, sometimes with deep conical or irregular cylindrical pits (Figure 12). Relief on this surface ranges up to 11 feet. The weathered zone is composed of reddish-brown

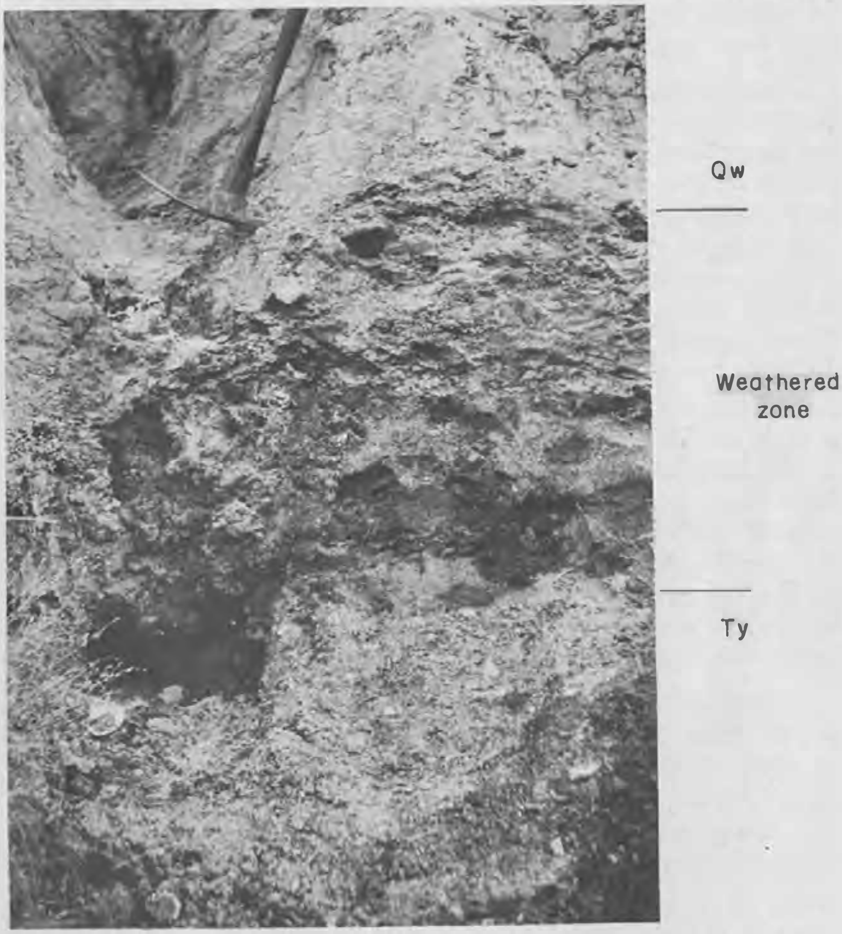

Figure 12. The weathered zone in the Yorktown Formation (Ty) that is overlain by the Windsor Formation (Qw) at O.D. Zook pit, is approximately one mile southwest of Yorktown on State Highway 238. The zone is reddish brown and dark gray. Internal molds of pelecypods are common and rudimentary bedding is preserved locally. The beds below the zone are oxidized yellowish brown and slightly cemented near the contact.

clayey sand and grades downward usually within 0.5 to 5 inches into a tan, soft, partially decomposed coquina. The clayey sand is composed of quartz and clay stained with iron oxide. Some mineral zones in unaltered sediment can be traced through the weathered zone in the pit. Some roots of living trees and bushes occupy the pits and may facilitate breakdown of the carbonate. Calcium carbonate leached by ground water from the overlying weathered zone has been precipitated in the unweathered sediments below as a sparry calcite cement. Clear to reddish brown calcite crystals up to 0.75 inches in length have been found in this zone of calcite precipitation.

Craggy coquinites crop out in the bluffs along the York River between Stony Point and Point of Rocks and also locally along the right bank of the James River. The coquinites are composed mostly of *Pecten* and *Ostrea* shells and fragments of other mollusks cemented by a sparry calcite cement. The porosity of this rock, locally, is about 65 percent. Molds of species of mollusks which construct aragonitic or magnesian calcite shells are also present. Ground water, and possibly salt spray from the York River, percolates down through the calcareous sediments and dissolves the more soluble aragonitic and calcitic specimens and leaves the more stable oyster and scallop shells. Because the area is well drained, the carbonate-bearing water either escapes or the carbonate is precipitated out as a calcite cement. Cementation does not occur in the lower bluffs because they are continually wetted by groundwater or salt spray. Wave attack on the unconsolidated lower part of the bluff undercuts the coquinite. Eventually large blocks of this material break off and fall on the beach or into the water forming a natural protective barrier against further immediate erosion.

In deeply buried sections of the Yorktown Formation, a ferricrete zone frequently occurs above sediments in the coquina or cross-bedded coquina facies. The ferricrete zone, 2 to 14 inches thick, is composed of sand and clay cemented by iron and manganese oxides. The ferricrete zone is usually a deep reddish-brown color and contains abundant external and internal molds of Yorktown mollusks. Bands of iron oxide frequently occur in the calcareous sediments at a distance below the ferricrete zone. Ground water bearing iron in solution percolates downward through the overlying sediments and reacts with the carbonate minerals in the coquina. The pH of the water increases as it comes in contact with the calcium carbonate. The iron and manganese oxides are then precipitated around the insoluble residue from the coquina, forming the ferricrete.

PLEISTOCENE SERIES

Windsor Formation

The Windsor Formation was named by Coch (1968) from a core boring near the town of Windsor, Isle of Wight County, Virginia. Coch traced the Windsor from the type locality eastward to the Suffolk scarp. Subsequently Bick and Coch (1969) have mapped the Windsor Formation in the Williamsburg area where it constitutes the surficial stratigraphic unit over the 70-foot and 90-foot plains east of the Surry scarp. In the Yorktown and Poquoson West quadrangles, the Windsor extends east to the Suffolk scarp and south to the Kingsmill scarp (Figure 3). Post-Windsor erosion has removed it from the area to the east and south of these scarps. The formation ranges in thickness up to approximately 45 feet and averages about 30 feet in the study area. The Windsor is evenly distributed over the major interfluvial area and slopes along both sides of the Peninsula. Excellent exposures of the Windsor Formation are found in O. D. Zook pit and along State Highway 143 in the Grove area where it rests unconformably on the Yorktown Formation (Figure 13).

Bick and Coch (1969) subdivided the Windsor Formation on the York-James Peninsula into two informal members, a lower cross-bedded sand and bedded silt member and an upper silty-clay, sandy-silt, and clayey sand member. These members were not delineated in the present study because of major vertical and lateral variations in lithology. Locally, in the Yorktown quadrangle, the lower Windsor contains a basal, medium to coarse, nonfossiliferous sand and gravel. The sand and gravel occurs in patches ranging in thickness from 0.2 feet thick to about 5 feet and grade upward into fine sand and clayey silt. The larger clasts are composed of quartz derived from rocks of igneous and metamorphic origin. The lower Windsor is thick to massively bedded with indistinct bedding planes marked by variations in grain size or mineral composition, principally discontinuous thin laminae of heavy minerals. In outcrop the bedding in the Windsor Formation appears nearly horizontal. Locally slumped portions and subsidence of the Windsor sedi-

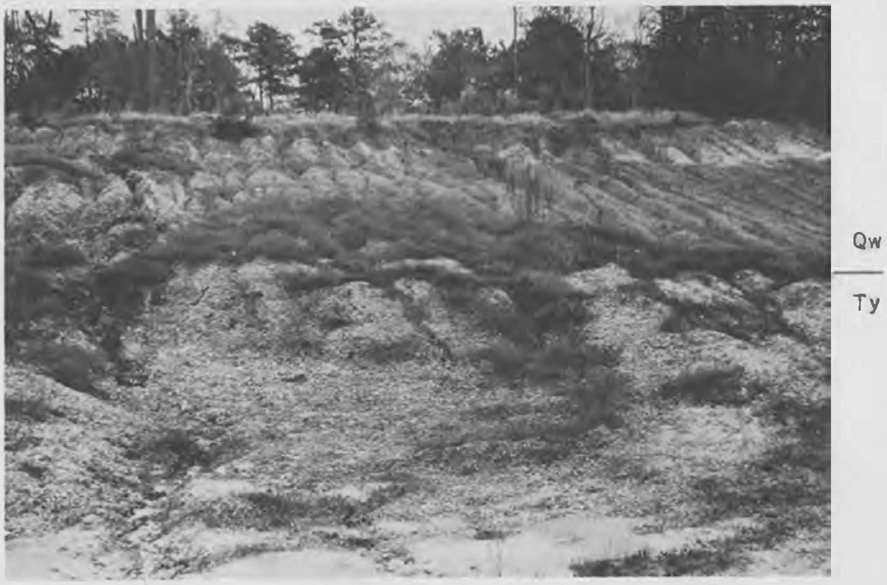

Figure 13. The Windsor Formation (Qw) disconformably overlying the Yorktown Formation (coquina facies) (Ty) in O.D. Zook pit, is approximately one mile southwest of Yorktown on State Highway 238. The Windsor consists of thin to massively bedded clayey silt and sand. The sand near the top of the section occupies a channel cut into the upper part of the Windsor Formation.

ments with contemporaneous deformation of the bedding planes have resulted from leaching of the calcareous sediments of the underlying Yorktown Formation. Upon weathering the silts commonly split into thin sheets that curl and become very friable.

The upper Windsor consists of a heterogeneous mixture of sand, silt, and clay that varies in color from medium gray to yellowish brown. Hematitic red streaks, developed along fracture planes by ground water percolating down through dessication cracks, commonly occur in more clayey sediments. Similarly, decayed roots are usually surrounded by gray sediment with mottled yellowish brown cavities. The depth of oxidation in these deposits varies from a few inches in poorly drained sandy clay to more than twenty feet in well-drained fine sand.

Two types of linear sand bodies occur in the upper Windsor. The first type is found along the toes of small scarps, such as the Lee Hall, and consists of discontinuous patches of indistinctly bedded, moderately well sorted, fine to medium sand that is light gray to yellowish brown in color. Pebbles are rarely found in these deposits. These bodies probably are remanents of beach or nearshore sands that accumulated locally along the eroding shoreline. The second type of sand body occupies small channels, 10 to 200 feet wide and 2 to 11 feet deep, cut into the finer grained sediments of the Windsor Formation. These sands exhibit marked vertical and lateral changes in texture, grading from fine sand to pebbly sand in two to five inches. Clay platelets are commonly mixed in with quartz sand of comparable size. Bedding planes are distinct and cross-bedding is confined to the channels. These sands appear to occupy paleotidal channels and, in some cases, subaerial stream channels.

Massively bedded, slightly clayey, fine to medium sands occur along the west side of the Suffolk scarp. These sands, as much as 18 feet thick, grade into the finer-grained silty and clayey facies to the west. The sand consists of about 80 percent sand and 20 percent silt and clay, lacks distinctive bedding planes, and contains some heavy minerals. The quartz grains are stained yellowish brown with iron oxides.

The only indigeneous fossils discovered in the Windsor Formation are vertical knobby burrows similar to those formed by *Calianassa major.* Other burrows of uncertain affinity were observed in sandy sediments of the upper Windsor. Locally, molds composed of goethite (?), hematite, and limonite were obtained from the basal part of the formation; these molds were of Yorktown mollusks and were reworked into the younger beds.

The Windsor Formation was deposited on a terrain of low relief (Plates 1, 2; Figure 5). The patches of sand and gravel at the base of the formation are probably fluvial-estuarine in origin whereas the overlying sediments were deposited under restricted marine conditions when the Windsor sea stood at approximately 100 feet above present sea level (Bick and Coch, 1969). The textural variation, distribution of sediments, sedimentary structures, fossils, and morphology of the upper Windsor suggest that it accumulated in shallow or shoaling water, probably a lagoonal environment with numerous tidal flats and channels, during the lowering of the Windsor sea.

The age of the Windsor Formation is uncertain because there has been no recovery of fossils of a definitive age. On the basis of its weathering characteristics and its stratigraphic position above the Bacons Castle formation and below the Norfolk Formation, it is assigned a Pleistocene age, possibly Yarmouth.

Norfolk Formation

In 1906 Clark and Miller established the Norfolk Formation from spoil heaps along the Dismal Swamp Canal in the vicinity of Norfolk, Virginia. Based upon extensive field work in southeastern Virginia, Oaks (1965) and Coch (1965, 1968) redefined the Norfolk and subdivided it into eight lithofacies. Bick and Coch (1969) and Coch (1971) traced the Norfolk Formation northward onto the York-James Peninsula. In the study area, the Norfolk, deposited under fluvial-estuarine, lagoonal, and shallow marine conditions, can be subdivided into five lithofacies, two of which are recognized by Coch (1968) south of the James River. The Norfolk rests unconformably upon the truncated edge of the Windsor Formation along the Suffolk, Kingsmill, and Camp Peary scarps and disconformably overlies the Yorktown or older formations elsewhere. The Norfolk Formation is the surficial stratigraphic unit over the Huntington flat, Hornsbyville flat, Hampton flat, and part of the Plumtree Island trough and ridge area. The Norfolk Formation crops out over most of the lower Middle Peninsula north of the York River.

Clayey-sand facies: The clayey-sand facies of the Norfolk crops out over the Huntington flat and in a discontinuous narrow belt between the York River and the Camp Peary scarp (Figure 3). Exposures of the facies may be seen in sand pits 0.3 to 0.7 mile north of the intersection of U. S. Highway 60 and State Highway 173 at Denbigh. It ranges in thickness from a feather edge against the scarps to more than 90 feet near the James River. Just east of Harwoods Mill the upper part of the unit was removed during erosion and a thin veneer of sand was deposited over the clayey-sand facies in the Tabb area. The clayey-sand facies disconformably overlies the Yorktown and Windsor formations.

The clayey-sand facies of the Norfolk Formation consists of interbedded sand, silt, and clay with thin beds of gravel locally (Figure 14). The strata are horizontal but exhibit great lateral and vertical variation in texture (Appendix I, Section D). In

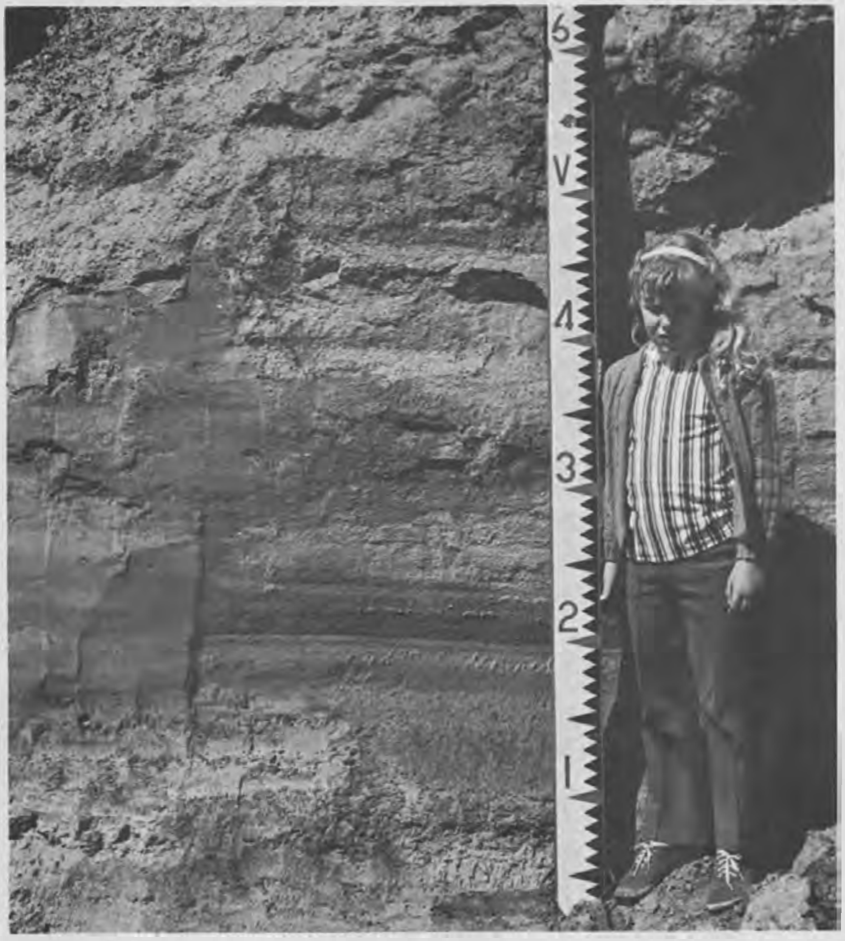

Figure 14. The clayey-sand facies of the Norfolk Formation exposed in an abandoned sand pit 0.25 mile north of Denbigh. The clayey-sand facies is characterized by marked variation in texture.

general a vertical sequence of this facies consists of a basal sand and gravel, a middle interbedded silt and sand, and an upper clayey sand. The basal unit consists of a medium to coarse sand with pebbly to bouldery quartzose gravel beds locally. The larger gravels are well-rounded, commonly subrectangular blocks of quartzite, weathered gneiss, and pegmatitic quartz. They were derived from the Piedmont and Blue Ridge provinces.

The light-gray sand in the basal unit is cross-stratified and the basal sand and gravel ranges in thickness to 22 feet.

The interbedded silt and sand sequence, locally more than 20 feet thick, consists of beds of medium gray silt, 1 to 22 inches in thickness, intercalated with thin beds of light-gray sand, 1 to 3 inches in thickness. The proportion of sand tends to decrease upward in the section. The quartz sand is fine to medium grained. Differential compaction of the sands and silts has produced wavy bedding in this unit. The silt varies from being thick bedded to laminated and contains small amounts of clay that makes it cohesive and resistant to erosion, even on moderate slopes. The upper 3 to 8 feet of the clayey-sand facies in the Denbigh area consists of massive beds of mottled gray and brown, clayey, fine to medium sand. Decomposed organic material and scattered pebbles occur in the clayey sand. This clayey sand has a blocky weathering characteristic. Drainage over much of the Huntington flat is poor because of the flatness of the terrain and the low permeability of the surficial clayey sand.

The only fossils observed in the clayey-sand facies of the Norfolk Formation in the study area consist of problematic burrows, mascerated plant leaves, and fragments of cypress stumps and trunks. However, brackish water fossil mollusks have been reported from the Norfolk Formation upstream from the study area (Bick and Coch, 1969).

Organic-silt facies: This facies occurs only in the subsurface in the south part of the Yorktown quadrangle and to the southeast of the map area. The organic-silt facies consists of interbedded organic-rich silt, clay, and peat, usually less than 20 feet thick. The silt, which varies in color between black and dark brown, constitutes the dominant portion of the facies. The clay is black to light gray in color, depending upon the abundance of organic material, and is sandy locally. Plasticity of the clay is high. The peat occurs in thin beds and is composed of partially decomposed woody material and mascerated plant remains. The facies is lenticular in cross section and is known to extend for more than four miles in a belt about one mile wide that trends northwest-southeast. The organic-silt facies grades laterally and vertically into the clayey-sand facies of the Norfolk Formation. The morphology, lithology, and stratigraphic relationships of this facies indicate that the organic-silt facies was deposited in an abandoned channel of the ancestral James River as sea level rose during Norfolk time.

Sand facies: The sand facies of the Norfolk Formation crops out in a belt about one mile wide along the Suffolk scarp. Outcrops are well exposed in road cuts along State Road 615 (Lakeside Road) opposite Grafton-Bethel School (Plate 2; Figure 15).

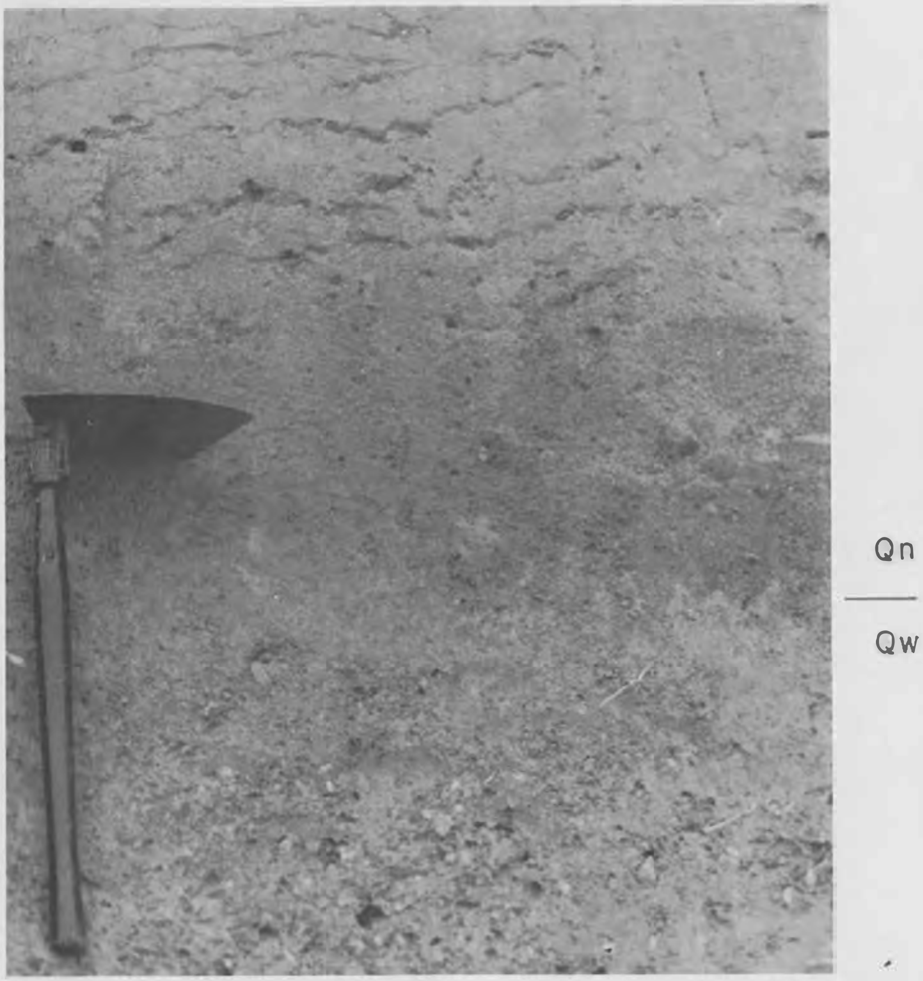

Figure 15. The sand facies of the Norfolk Formation (Qn) resting unconformably on the Windsor Formation (Qw) on State Road 615 opposite Grafton-Bethel School. The shovel blade marks the unconformity between the overlying medium to gravelly sand and the reddish-brown, gravelly, clayey sand below.

The prism-shaped sand body ranges in thickness from a feather edge along the scarp to nearly 20 feet. The maximum elevation of the sand facies along the Suffolk scarp is about 48 feet. To the east it grades into the sandy clay facies. The sand facies exhibits marked vertical and lateral variations. The basal sediments in the facies are commonly gravelly sand with boulders up to eight inches in diameter (Appendix 1, Section A). The coarse fraction of the gravelly sand is usually pea gravel. The gravelly sand is cross-bedded locally. The overlying sediments are composed of thin- to thick-bedded, fine to coarse, gray quartzose sand. Small-scale cross beds are commonly accentuated by heavy mineral-bearing laminae. Heavy minerals are concentrated locally within the sequence and are locally abundant throughout the sand facies. Although the trend is not observed everywhere in the sand facies, the sand decreases in grain size from west to east. The uppermost beds exhibit little or no bedding, but contain irregular mineral or organic-rich, brown bands formed by weathering of the heavy minerals and movement of humic acids downward in the sand. The uppermost sand is light gray to yellowish brown and grades downward into a gray or tan in the lower part. The only fossils observed in the sand facies are poorly defined burrows. The lithology, primary sedimentary structures, and morphology of the sand facies indicate that it was deposited under shallow nearshore marine and beach conditions.

Sandy-clay facies: This facies is the surficial stratigraphic unit over most of the Hampton flat (Figure 3) and ranges in thickness from about 15 feet near the Big Bethel scarp to less than 10 feet near Poquoson (Plate 2, W-2604). A cobble zone with flattened quartzose boulders up to 12 inches in diameter commonly marks the unconformity between the sandy-clay facies of the Norfolk and the underlying Yorktown Formation. The sediments in the lower part of the sandy-clay facies are sandy clay and clayey sand with varying proportions of pea gravel. These sediments are unsorted and in places stained reddish brown. In the upper part of this facies the amount of sand diminishes eastward from the Big Bethel scarp. Because of the high water table over much of the area, oxidation has not taken place to depths greater than three feet. In the Poquoson area the relatively impermeable sandy-clay facies prevents ground water in the more permeable shelly-sand facies of the Yorktown Formation from rising above the unconformity. Consequently deeper excavations in this area are frequently flooded by ground water. The boundary between the sandy-clay and silty-sand facies is drawn arbitrarily along a small topographic break between the 5 and 10 foot contour lines. The sandy-clay facies appears to have been formed from older Norfolk sediments reworked during the recession of the Norfolk sea.

Silty-sand facies: This facies of the Norfolk crops out in ridges in Goodwin Islands (Plate 2), Crab Neck (Plate 2, W-2593), Plumtree Island (Plate 3). The low areas between the ridges are filled with Holocene tidal flat and marsh, organic clay, and silt. The basal sediments in the silty-sand facies consist of medium- to dark-gray, silty and clayey sand that locally has gravel. In places lag cobbles with maximum lengths of 14 inches mark the unconformity between the Yorktown and the silty-sand facies. Thin beds of silty clay are found locally in the lower part of the facies. The ridges are composed of fine to medium sand, with less than 10 percent silt and clay. Small quantities of gravelly sand occur locally on the ridges. On the broader ridges the sediments are slightly finer on the west side than on the east side of the ridges. The sand on the crest of the ridge lacks distinctive primary sedimentary structures and shows shallow weathering profiles. The silty-sand facies is usually less than 10 feet thick.

The silty-sand facies was deposited under bay-tidal, flat-beach conditions. Although the possibility exists that these deposits were formed by progradation following the Holocene rise of sea level, the lack of fossils in these deposits, the compaction of the sediments, and the dissection of the ridges by transverse flowing rivers suggest that they date from the late Sangamon. Charts of the Poquoson Flats and Drum Island Flats indicate that this area has undergone severe erosion rather than progradation during the last three centuries.

HOLOCENE SERIES

Sediments of Holocene age occur along the York and James rivers, in their tributaries, and along the Chesapeake Bay. These sediments unconformably overlie older formations. Alluvial sand and organic-rich silt and clay occur in the upper reaches of tidal streams. Locally, man-made impoundments have created marshlands and lakes in which organic materials and terrigenous sediment are accumulating. These deposits are thin compared to those in the lower reaches of the smaller tidal streams and major rivers where more than 50 feet of Holocene sediment has been deposited locally. These sediments consist of beach sand and estuarine interbedded sand, silt, and clay. The beach and nearshore sand commonly contains pebbles, shell fragments, blocks of coquinite, and artifacts derived by beach erosion from the Yorktown, Windsor, and Norfolk formations and the man-made, shore-protection structures. In places, indigenous faunas contribute significant amounts of shell material.

Sand and clay deposits of uncertain age occur in the linear ridges on Mulberry Island (Plate 1). Since no deep borings were made in this area the relationship of these sediments to the underlying deposits is not known. Sediments taken from core samples at -10 feet elevation in this area consist of gray, fine to coarse sand with scattered pea gravel. The interval from -8 feet elevation to about sea level contains gray to yellowish-brown fine sand. The sediments above sea level are composed of plastic clay with lesser amounts of silt and fine sand that grades downward into the fine sand. The troughs between the ridges are filled by recent organic silts and clays with lesser amounts of sand. Wind-blown sand occurs locally along the James and York rivers.

Salt marshes in the Plumtree Island trough and ridge area have trapped suspended sediment. Most of this sediment consists of organic silt and clay, but locally sand that has been washed over the marshes during storms is found interbedded or overlying the organic silt and clay. The marsh deposits are usually less than 5 feet thick and are restricted to the troughs.

GEOLOGIC HISTORY

During late Mesozoic time downwarp in the Delaware-Virginia coastal region established the basic structural and sedimentary regime that persisted through most of Cenozoic time. Subsidence in this area was rapid in the late Mesozoic and early Cenozoic and terrestrial, deltaic, and shallow marine sediments were deposited as the seas rose and fell (Spangler and Peterson, 1950). By late Miocene a shallow sea had invaded what is now the Tidewater area. Terrigeneous sediments carried by the ancestral Coastal Plain streams were deposited in the shallow marine environment (Williamsburg area), forming the sand facies deposited in Yorktown time (Johnson, 1969). In the warm, relatively shallow seas (Yorktown area), mollusks grew in profusion creating localized shell banks on the sea floor. As the shell banks grew upward, waves and north-flowing longshore currents swept over them, fragmenting and transporting the shell westward and northward over the sea floor. Shell banks coalesced and formed a major submarine bar system (cross-bedded coquina facies) and extended from Yorktown to Chuckatuck (Johnson and Coch, 1969). The bar system was one to two miles wide at this time. Landward of the bar was a broad lagoon 25 to 50 feet deep that extended from the vicinity of Yorktown to a shoreline west of Williamsburg. Fine sand, silt, and clay from land and silt and clay-sized shell fragments from the bar complex were deposited in the lagoon (sandy-silt facies). Occasionally storm-generated waves carried shell hash out into the lagoon. On the seaward side of the barrier, the water ranged from 50 to 125 feet in depth. In the deeper water wave action and bottom currents were weak and fine sand, silt, and shell were deposited (silty-sand facies). Eventually the barrier system was breached or drowned and the lagoonal area became populated by a prolific and diverse molluscan fauna. In the absence of terrigeneous material, the coquina and *Chama* facies formed.

In late Miocene or early Pliocene time sea level began to fall (Hazel, 1971) and a portion of the sea floor emerged. The upper beds of the Yorktown were weathered and slightly dissected. Presumably, a mantle of sand, clay, and gravel of the Bacons Castle formation was deposited on this surface but was later removed during a late Pliocene and/or early Pleistocene episode of erosion. The lower part of the Windsor Formation was deposited during the advance of the shoreline to the Surry scarp (100 feet). A barrier developed, possibly near the present position of the Suffolk scarp, and lagoonal sedimentation occurred (Yorktown area). Late in this period sea level began to fall in stages, creating small strandline scarps (Figure 16 A, B).

During the succeeding low stand of the sea, the ancestral James channel was excavated and small streams began to erode headward into the uplands underlain by the Windsor (Figure 5). With the melting of the Illinoian glaciers the sea rose to 45 to 50 feet above present sea level (Figure 16 C). Organic silt and peat accumulated in marshes along drowned stream channels. With the rise of sea level fluvial-estuarine sediments were deposited along the courses of the ancestral James and York rivers. Initially they were sands and gravels, but later sand,

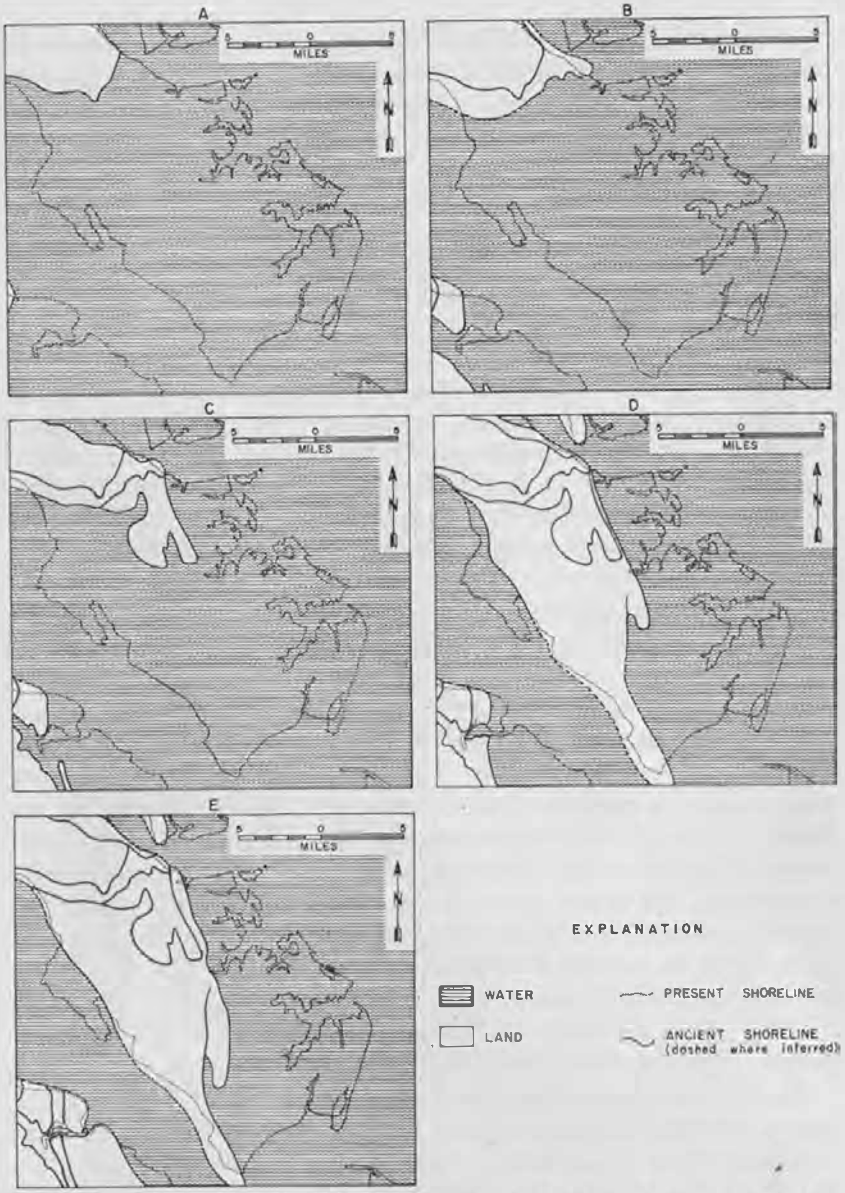

Figure 16. Paleogeography of the lower York-James Peninsula during middle and late Windsor times and during middle and late Norfolk times:
A Middle Windsor time, sea level at approximately 70 feet;
B Late Windsor time, sea level at approximately 55 feet;
C Middle Norfolk time, sea level at approximately 45 feet;
D Early late Norfolk time, sea level at approximately 30 feet;
E Middle late Norfolk time, sea level at approximately 20 feet.

silt, and clays were deposited as the gradient on the James and York rivers decreased. The mainland beach lay near the east side of the Suffolk scarp. Under wave and longshore current attack, the mainland beach retreated. When sea level fell to about 30 feet, the main part of the fluvial-estuarine plain, the Huntington flat, emerged and was eroded (Figure 16 D). Sediment derived from the erosion of the mainland beach along the Suffolk scarp was transported southward by longshore currents. This sediment was deposited southeastward as a spit. Continued fall of the sea exposed the Hornsbyville flat that then was eroded by waves and currents along its east side (Figure 16 E). Much of the sediment cover over the Hampton flat was stripped away and this stage of erosion produced the Big Bethel scarp, a middle late Norfolk mainland beach along the west side of the ancestral Chesapeake Bay. Spit formation continued to the southeast with the addition of sediment derived from the beach to the north. The trough and ridge topography from the Goodwin Islands to Plum Tree Island was constructed during the recession of the Norfolk sea as it approached present sea level.

During the Wisconsin interglacial time the lower York-James Peninsula was emergent and most of the streams in this area were tributaries of the Susquehanna River, which flowed through the Chesapeake lowland. The James, York, Warwick, and Poquoson rivers cut deep channels into the Norfolk and older sediments. Channelling by the James River in the Mulberry Island area extended below –90 feet.

The Holocene rise of sea level resulted in the filling of these deep valleys with fluvial-estuarine sediments. Wave action has caused cliff recession along the major streams and has contributed to the destruction of several islands that once existed in the Poquoson Flats area. The thin marsh sediments were deposited in the troughs on Plumtree Island area during this period. Flooding along the James River may have produced the clayey sediments on Mulberry Island.

ECONOMIC GEOLOGY

The principal mineral resources in the map area are marl and sand and gravel which are used for general construction and road fill. Formerly, naturally cemented marl was quarried from the bluffs along the south bank of the York River and was used in the construction of buildings, such as Grace Church in Yorktown. This marl was also extracted from the Yorktown area for agricultural lime; it is being intermittently produced at the O. D. Zook pit southwest of Yorktown (Plate 1). The marl is used extensively for highway subgrade and locally for surface material on secondary roads. Sediments from the silty sand facies of the Yorktown Formation are extracted from pits in the Grafton-Hornsbyville area for use as fill on construction sites and for highway subgrade. These deposits are overlain by the sand facies of the Norfolk Formation.

Sand and gravel are recovered from the sand facies of the Norfolk Formation on the Hornsbyville flat (Plate 2) and from the clayey-sand facies of the Norfolk on the Huntington flat (Plate 1). The sand and gravelly sand are trucked to the users on the lower York-James Peninsula. Pits in the Grafton area operated by R. L. Brandt and Sons and Lowe Construction Company, Inc. yield quartzose sand for fill. The sand deposits range in thickness from 8 to more than 20 feet in thickness locally and extend from the vicinity of Grafton north to the York River. As the sand deposits are depleted, the operators commonly begin excavating the underlying silty-sand facies of the Yorktown Formation.

In the Denbigh area, clayey sand, which is sold for fill, overlies thick sand and gravelly sand deposits within the clayey-sand facies of the Norfolk Formation. The sand is utilized in general construction work as well as for fill. These deposits occur in linear tracts that trend northwest-southeast and exceed 35 feet in thickness. E. W. Muller, Contractor, Inc. intermittently operates a pit to the north side of State Highway 173 near Denbigh (Plate 1) to produce sand for use as fill and in the company's asphalt plant. The number of active sand and gravel pits in the Denbigh area has declined in recent years as the deposits are exhausted or as extraction is no longer feasible because of the encroachment of housing subdivisions and commercial establishments and zoning restrictions. During the construction of Interstate Highway 64, many borrow pits were opened along the right-of-way in the Windsor and Norfolk formations; all are now inactive.

As the population on the lower York-James Peninsula increases, the demand for solid waste disposal sites will grow. Presently abandoned sand and marl pits on the Hornsbyville flat are being used for the disposal of flyash from the nearby coal-burning electric power plant on the York River east of Yorktown. Demand for flyash disposal sites will decline sharply within the next few years when the power plant converts from coal to oil. In the meantime, the depleted extraction pits in the area appear sufficient to meet the needs for flyash disposal sites.

York County operates a sanitary landfill site about 0.5 mile north of Grafton. Potential landfill sites exist along the Suffolk scarp near Hornsbyville and along the Kingsmill scarp near Patrick Henry Airport where ground water table is low, surface drainage is adequate, and the underlying Yorktown Formation is relatively impermeable. These conditions inhibit the leaching of deleterious materials from the landfill and thereby reduce the probability of contamination of surface and ground water. In addition, sites in the proposed areas are accessible by improved roads and the environmental impact, both biologic and aesthetic, will be minimal.

Reclamation of mined-out areas and landfill sites is important to the preservation and enhancement of water and land resources in this area. Ungraded barren slopes are eroding and causing silting of streams and degradation of their water quality, locally. Some abandoned pits have been improved as lake sites and will be subdivided in the future.

REFERENCES

Bick, K. F., and Coch, N. K., 1969, Geology of the Williamsburg, Hog Island, and Bacons Castle quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 18, 28 p.

Bowman, J. R., and others, 1968, The origin and development of a coquina facies of the Yorktown Formation near Chuckatuck, Virginia (abs.) : Virginia Jour. Sci., vol. 19, p. 194.

Clark, W. B., and Miller, B. L., 1906, Geology of the Virginia Coastal Plain, *in* The clay deposits of the Virginia Coastal Plain: Virginia Geol. Survey Bull. 2, p. 11-24.

——— 1912, The physiography and geology of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 4, 222 p.

Coch, N. K., 1965, Post-Miocene stratigraphy and morphology, inner Coastal Plain, southeastern Virginia: Office of Naval Research, Geography Branch, Tech. Rept. No. 6 (Ph. D. dissertation, Yale Univ.), 97 p.

——— 1968, Geology of the Benns Church, Smithfield, Windsor, and Chuckatuck quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 17, 40 p.

——— 1971, Geology of the Newport News South and Bowers Hill quadrangles, Virginia: Virginia Division of Mineral Resources Rept. Inv. 28, 26 p.

Gibson, T. G., 1970, Late Mesozoic-Cenozoic tectonic aspects of the Atlantic coastal margin: Geol. Soc. America Bull., vol. 81, p. 1813-1822.

Hazel, J. E., 1971, Paleoclimatology of the Yorktown Formation (upper Miocene and lower Pliocene) of Virginia and North Carolina: Bull. Centre Rech. Pau—SNPA, 5 suppl., p. 361-375.

Johnson, G. H., 1969, Geology of the lower York-James Peninsula and south bank of the James River: College of William and Mary Dept. Geology, Guidebook no. 1, 33 p.

Johnson, G. H., and Coch, N. K., 1969, A coquina facies in the Yorktown Formation near Chuckatuck, Virginia and its geological implications *in* Abstracts for 1968: Geol. Soc. America, Special Paper 121, p. 448.

Lyell, Charles, 1845, On the Miocene Tertiary strata of Maryland, Virginia, and of North and South Carolina: Geol. Soc. London Quart. Jour., vol. 413-427.

MacNeil, F. S., 1938, Species and genera of Tertiary Noetinae: U. S. Geol. Survey Prof. Paper 189-A, 49 p.

Mansfield, W. C., 1943, Stratigraphy of the Miocene of Virginia and Miocene and Pliocene of North Carolina, *in* Gardner, J. A., Mollusca from the Miocene and lower Pliocene of Virginia and North Carolina: U. S. Geol. Survey Prof. Paper 199-A, p. 1-18.

Murray, Grover, 1961, Geology of the Atlantic and Gulf Coastal province of North America: New York, Harper and Brothers, 692 p.

Oaks, R. Q., 1965, Post-Miocene stratigraphy and morphology, outer Coastal Plain, southeastern Virginia: Office of Naval Research, Geography Branch, Tech. Rept. No. 5 (Ph. D. dissertation, Yale Univ.), 240 p.

Roberts, J. K., 1932, The lower York-James Peninsula: Virginia Geol. Survey Bull. 37, 58 p.

Rogers, W. B., 1884, A reprint of annual reports and other papers on the geology of the Virginias: New York, D. Appleton and Co., 832 p.

Spangler, W. B., and Peterson, J. J., 1950, Geology of Atlantic Coastal Plain in New Jersey, Delaware, Maryland, and Virginia: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 1-99.

Stephenson, L. W., Cooke, C. W., and Mansfield, W. C., 1933, Chesapeake Bay region: Internat. Geol. Cong., 16th United States 1933, Guidebook 5, Excursion A-5, 49 p.

U. S. Geological Survey, 1965, Geological Survey research 1965: U. S. Geol. Survey Prof. Paper 525-A, p. A71.

Wentworth, C. K., 1930, Sand and gravel resources of the Coastal Plain of Virginia: Virginia Geol. Survey Bull. 32, 146 p.

APPENDIX I

REFERENCE SECTIONS

All reference sections were measured in outcrops. Core-boring records of the described section for the hand-auger boring in Section C are on file at the Virginia Division of Mineral Resources.

SECTION A: YORKTOWN FORMATION (SILTY-SAND FACIES) AND NORFOLK FORMATION (SAND FACIES)

Exposure in sand pit about 0.25 mile NW of State Road 615, 0.25 mile NE of Grafton-Bethel School, York County. Pit owned by R. L. Brandt and Sons. Elevation at top of section is approximately 31 feet.

	Thickness Feet
Norfolk Formation, sand facies	
Sand, brown to dark-gray, medium to fine, silty; slightly cohesive, grades into underlying sand	1.5
Sand, tan to light-gray, fine to coarse; irregular reddish-brown bands in upper part; medium to thick bedded, some small-scale cross bedding; contains small lenses of silt and clay	9.5
Sand, medium-gray, coarse to fine; contains scattered quartz pebbles, bedding indistinct, some cross bedded; locally contains gravels near base, discontinuous cobble zone at base	3.2
Yorktown Formation, silty-sand facies	
Sand, yellowish-brown to medium-gray, mottled, fine, clayey; slightly cohesive, soft; noncalcareous, distorted shell molds common	2.3
Sand, greenish-gray, fine, silty; calcareous, slightly micaceous, friable when dry; zones of abundant fossils, mainly *Crepidula* at 2- to 3-foot intervals, some shells in original life position, others randomly oriented; grades downward into more clayey, silty, fine sand	14.5 (exposed)

A partial listing of the fauna from this locality is in Appendix II, list B. The fauna is marine and contains a dominance of infauna elements, especially among the pelecypods. The upper Yorktown is weathered and the disconformity is marked by a change in color and texture of the sediments.

SECTION B: YORKTOWN FORMATION (CROSS-BEDDED COQUINA FACIES)

Exposure in abandoned marl pit 400 feet SW of *cul de sac* on Marl Ravine Road (Virginia Road 1201). Section measured by G. H. Johnson, May, 1969. Elevation at top of section is approximately 50 feet.

	Thickness Feet
Windsor Formation	
Sand, yellowish to reddish-brown, fine to medium, clayey; mottled, slightly plastic; grades downward into the underlying sand	3.1
Sand, light-gray to yellowish-brown, fine to medium, silty; thin to thick bedded, nonfossiliferous, lower part oxidized	9.5
Yorktown Formation, cross-bedded coquina facies	
Sand, reddish-brown to dark-gray, fine to medium; cemented by iron oxides, contains fossil molds, discontinuous; undulatory surface, grades downward into unit below	2.8-5.6
Coquina, tan to yellowish-brown, medium to coarse; calcareous sand with abundant whole shells; upper part crumbly, partially cemented by calcite; shells of *Chlamys*, *Mercenaria*, and *Ostrea* oriented parallel to bedding	0.0-2.8
Coquina, tan, fine to medium; biofragmental sand; friable, bedding thick, cross bedded, cross bed sets 5 to 16 inches thick, dip is toward NW at 12 to 26 degrees; moderately sorted, shell fragments well rounded; whole shells lacking, dominantly molluscan fragments; burrowed	16.0 (exposed)

This locality exposes a thick sequence of the cross-bedded coquina facies.

SECTION C: YORKTOWN FORMATION (SANDY-SILT AND COQUINA FACIES) AND WINDSOR FORMATION

Exposure and hand auger in active marl pit on west side of State Highway 238 one mile SW of Yorktown. Operated by O. D. Zook. Section measured by G. H. Johnson, June, 1968. Elevation at top of section is 72 feet.

	Thickness Feet
Windsor Formation	
Sand, grayish-brown to medium-gray, fine, silty, clayey; lower part mottled, cohesive	1.3
Sand, light-gray to yellowish-brown, fine to coarse; locally cross stratified, gravelly lenses, scattered clay platelets	0.0-7.2
Sand and silt, medium-gray, interbedded; sand is fine, well sorted, composed of quartz, thin to thick bedded, burrowed; silt is clayey, cohesive, weathers into thin sheets, contains joint planes coated with yellowish-brown iron oxide	22.8

	Thickness Feet
Yorktown Formation, coquina facies (27.0 feet)	
Sand, reddish- to yellowish-brown, cemented with iron oxides; molds of fossils, locally soft, uncemented	1.2-3.9
Coquina, tan, mottled reddish- and yellowish-brown; partially decomposed, crumbly, medium to fine biofragmental sand	0.8-1.9
Coquina, tan, biofragmental medium to fine sand and whole shells; locally cemented with calcite, *Lemintina* biostrome locally near top of section, mollusks dominate fauna with abundant epifauna *(Ostrea, Pseudochama, Glycymeris, Balanus)* and infauna *(Mercenaria, Dosinia, Ensis, Panope)*, many in original living position, marked lateral and vertical variation in fauna	23.0
Covered	6.0
Yorktown Formation, sandy-silt facies	
Silt, medium-gray, sandy, clayey; interspersed with biofragmental sand, extensively burrowed, burrows filled with shell hash, interbedded with thin beds of biofragmental sand, fossil content decreases downward	12.0

The sandy-silt facies contains a limited fauna in contrast to the overlying coquina facies. The change in fauna and sediments indicate shallowing of the sea and finally emergence. The undulatory surface on the weathered Yorktown and different character of the weathered zone within the pit indicates that this zone experienced a compound weathering history. The Windsor Formation at this locality exhibits the complex variations in sediments that are typical of the formation over its outcrop area.

SECTION D: NORFOLK FORMATION (CLAYEY-SAND FACIES)

Exposure in west wall of sand pit along Stony Run, 0.1 mile north of U. S. Highway 60, 0.3 mile NW of Denbigh. Elevation at top of section is approximately 28 feet.

	Thickness Feet
Soil removed	
Norfolk Formation, clayey-sand facies	
Sand, gray to yellowish-brown, clayey, silty; scattered pebbles, stiff, joints upon drying, oxidized yellowish-brown along joints	6.3
Sand, tan to light-gray, fine to medium, thin- to medium-bedded, cross stratified, quartzose; contains laminae and thin beds of light-gray silt and clay; scattered pebbles, grades downward into underlying unit	5.2

	Thickness Feet
Silt and sand, light- to medium-gray, interbedded; silt is laminated locally, weathers into thin sheets, gradational into sand beds below	7.1
Sand, light- to medium-gray, fine to coarse; cross stratified, contains lenses of gravelly sands; scattered tabular boulders up to 19 inches in diameter dredged from below water line	2.6

The clayey-sand facies exhibits considerable lateral and vertical variation within this pit.

APPENDIX II

FAUNAL LIST OF YORKTOWN FORMATION

Facies: A and B, silty-sand; C, cross-bedded coquina; D, shelly-sand; E, coquina. Locations cited at end of Appendix II. Fossil specimens are in the repository of the Virginia Division of Mineral Resources, Charlottesville, Virginia.

	A	B	C	D	E
Porifera					
Cliona sp.	x	x	x	x	x
Coelenterata					
Astrangia lineata (Conrad)	–	x	x	x	x
Brachiopoda					
Discinisca lugubris (Conrad)	–	–	–	–	x
Bryozoa					
Cheilostomata	x	x	x	x	x
Scaphopoda					
Cadulus thallus (Conrad)	x	x	–	–	x
Dentalium carolinense Conrad	–	x	–	x	x
Gastropoda					
Aurinia mutabilis (Conrad)	x	–	–	–	x
Busycon canaliculatum Linnaeus	–	x	–	–	–
Busycon carica (Gmelin)	–	–	–	–	x
Busycon tritone Conrad	–	x	–	–	x
Calliostoma conradi Gardner	–	x	–	–	–
Calliostoma mitchelli (Conrad)	–	x	–	–	–
Calliostoma philanthropum (Conrad)	–	x	–	–	x
Cancellaria cf. *C.* perspectiva Conrad	–	x	–	–	–
Compsodrillia chowanensis Gardner	–	x	–	–	–
Crepidula aculeata costata Morton	x	x	x	x	x
Crepidula fornicata (Linnaeus)	x	x	x	x	x
Crepidula plana Say	x	x	–	x	x
Crucibulum costatum (Say)	–	x	–	–	x
Cypraea sp.	–	x	–	–	–
Diodora redimicula (Say)	–	x	x	x	x
Ecphora quadricostata (Say)	–	x	x	–	x
Epitonium sp.	–	x	–	–	x
Epitonium pratti Gardner	x	–	–	–	–
Eupleura caudata (Say)	–	x	–	–	–
Fusinus burnsii (Dall)	x	–	x	–	x
Fusinus exilis (Conrad)	–	x	–	–	x
Ilyanassa sp.	–	x	–	–	–
Lemintina granifera (Say)	x	x	–	x	x
Lunatia heros (Say)	x	x	–	–	x
Marginella limatula Conrad	–	x	–	–	x

	A	B	C	D	E
Mitrella sp.	–	–	–	x	x
Mitrella lunata (Say)	–	x	–	–	–
Murex sp.	–	x	–	–	–
Oliva sayana Ravenel	x	x	–	–	–
Polynices duplicatus (Say)	–	–	–	–	x
Ptychosalpinx fossulata (Conrad)	–	x	–	–	–
Ptychosalpinx laqueata (Conrad)	–	x	–	–	–
Scalaspira strumosa Conrad	–	x	–	–	–
Terebra sp.	–	x	–	–	–
Turritella alticostata Conrad	–	x	x	x	x
Urosalpinx cinerea (Say)	–	x	–	–	–
Urosalpinx rusticus (Conrad)	–	x	–	–	–
Urosalpinx trossula (Conrad)	–	–	–	–	x
Uzita chowanensis Gardner	–	x	–	–	–
Pelecypods					
Abra sp.	x	–	–	–	–
Astarte concentrica Conrad	x	x	x	–	x
Astarte symmetrica Conrad	x	–	x	–	–
Astarte undulata Say	x	–	–	–	x
Barbatia centenaria (Say)	–	–	–	x	–
Callocardia sp.	–	–	–	–	x
Callocardia sayana (Conrad)	–	x	–	–	–
Carditamera arata Conrad	–	–	x	–	x
Cerastoderma sp.	x	–	–	x	–
Cerastoderma laqueatum (Conrad)	–	x	–	–	x
Cerastoderma virginianum (Conrad)	–	x	–	–	–
Chama congregata Conrad	x	x	x	–	x
Chlamys eborea (Conrad)	x	x	x	x	x
Chlamys jeffersonia (Say)	–	–	x	–	x
Corbula cuneata Say	–	–	–	–	x
Corbula conradi retusa Gardner	–	–	–	–	x
Dosinia acetabulum Conrad	–	x	–	–	–
Ensis sp.	x	–	–	–	–
Ensis directus (Conrad)	–	x	–	–	x
Eucrassetella undulatus (Say)	x	x	x	–	x
Glycymeris americana (DeFrance)	x	x	x	–	x
Glycymeris subovata (Say)	x	x	x	–	x
Kuphus calamus (H. C. Lea)	–	x	–	–	–
Mercenaria campechiensis (Gmeiln)	x	x	–	–	–
Mercenaria cf. *M. rileyi* (Conrad)	–	–	x	–	–
Mercenaria tridacnoides (Lamarck)	–	–	x	x	x
Noetia incile (Say)	–	x	x	x	x
Nucula proxima Say	x	x	–	–	x
Ostrea disparilis Conrad	–	x	x	x	x
Ostrea sculpturata Conrad	x	x	x	–	x
Pandora crassidens Conrad	–	x	–	–	–
Panope cf. *P. goldfussi* Wagner	–	–	–	–	x
Panope reflexa (Say)	–	x	–	–	–
Petricola cf. *P. harrisi* Dall	–	x	–	–	x

	A	B	C	D	E
Phacoides anodonta (Say)	–	x	–	–	–
Plicatula marginata Say	–	–	x	x	x
Pseudochama corticosa (Conrad)	x	–	x	–	x
Saxicava artica (Linnaeus)	–	–	–	–	x
Semele subovata (Say)	–	x	–	x	–
Spisula delumbris (Conrad)	–	x	–	–	–
Spisula cf. *S. modicella* (Conrad)	x	–	–	–	–
Tellina sp.	x	–	–	–	–
Tellina aequistriata Say	–	x	–	–	–
Venericardia granulata Say	x	–	x	x	x
Yoldia laevis (Say)	x	x	–	–	–
Unidentified boring clam	–	–	x	x	x
Annelida					
Polydora sp.	x	x	x	–	x
Spirorbis sp.	x	x	–	x	x
Arthropoda					
Balanus concavus Brown	–	x	x	x	x
Decapod fragments	–	–	–	–	x
Echinodermata					
Echinoid spines and plates	–	x	–	–	–
Pisces					
Fish vertebra	–	x	–	–	–
Mammalia					
Orycterocetus (?) tooth (Identified by F. C. Whitmore; Repository of U. S. National Museum)	–	x	–	–	–

A—Fossils from spoil piles on east side of Bennett Creek, 0.3 mile northwest of the junction of State Road 172 and North Lawson Road (Poquoson East quadrangle). Approximate elevation from which fossils were dredged is –5 to –10 feet mean sea level; fossils were collected and identified by G. H. Johnson.

B—Fossils recovered from spoil piles and working face of pit of R. L. Brandt and Sons, 0.25 mile northeast of Grafton-Bethel School (Poquoson West quadrangle). Sampled interval is between 9 and 18 feet mean sea level. Fossils were collected by G. H. Johnson and D. W. Neal and identified by G. H. Johnson, D. W. Neal, and K. R. Davis.

C—Exposure in abandoned marl pit in valley 300 feet south of *cul-de sac* at west end of Marl Ravine Road, 2.0 miles southeast of Yorktown, Virginia. Fossils were collected from uppermost fossiliferous bed by G. H. Johnson and identified by G. H. Johnson, K. R. Davis, and D. W. Neal.

D—Exposure along south bank of York River 300 feet above Moore House. Fossils from the shelly-sand facies about 2.0 feet above mean sea level were collected and identified by G. H. Johnson.

E—Exposure and spoil piles in marl pit west side of State Highway 238, 1.0 mile southwest of Yorktown. Pit owned and operated by O. D. Zook. Fossils from the coquina facies were collected and identified by G. H. Johnson.

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